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A REFERENCE HANDBOOK

OF

THE MEDICAL SCIENCES

EMBRACING THE ENTIRE RANGE OF

SCIENTIFIC AND PRACTICAL MEDICINE

AND

ALLIED SCIENCE

BY VARIOUS WRITERS

A NEW EDITION, COMPLETELY REVISED AND REWRITTEN

EDITED BY ALBERT H. BUCK, M.D
NEW YORK CITY

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VOLUME II.

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A REFERENCE HANDBOOK

OF

THE MEDICAL SCIENCES.

BLASTODERM.—Blastoderm is a term of somewhat varied signification according to the animal to which it is applied, and, indeed, according to the stage of development. The blastoderm of vertebrates is different from the so-called blastoderm of many invertebrates. The term is applied especially to meroblastic ova, but is also used in reference to the mammalian ovum; it designates the layer or layers of cells which partially or completely cover the yolk and directly participate in the formation of the embryo. *The blastoderm may be defined as the stratum of cells resulting from segmentation of the ovum, and not belonging to the yolk.* We cannot enter into a detailed comparison of the blastoderm throughout the animal kingdom; let it suffice to point out that the structures so called are by no means always homologous. Thus, in insects, segmentation is partial and produces a single layer of cells (Fig. 499), which gradually spreads over the yolk and apparently represents only the ectoderm. In vertebrates, however, the blastoderm is more complex, and consists, in most forms, of several layers of cells, or rather at first of a thick stratum of cells not separated into distinct layers until later stages. The typical vertebrate blastoderm can, perhaps, be best seen in the eggs of bony fishes. The disposition has been very carefully studied by Dr. C. O. Whitman, to whom I am indebted for the accompanying semi-diagrammatic figure (Fig. 500) of the ovum and blastoderm of a flounder. The ovum is surrounded by a vitelline membrane, *z*,

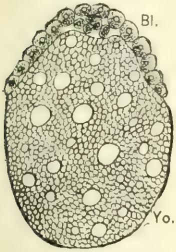

FIG. 499.—Section of Egg of Oniscus Murarius. (After Bobretzky.)

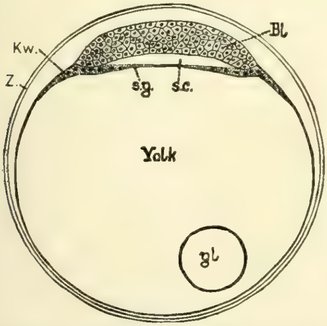

FIG. 500.—Ovum of a Flounder in Transverse Vertical Section, Semidiagrammatic. *z*, Vitelline membrane; *kw*, segmenting zone (Keimwall); *Bl*, blastoderm; *s.c.*, segmentation cavity; *s.g.*, subgerminal plate; *gl*, oil globule of yolk.

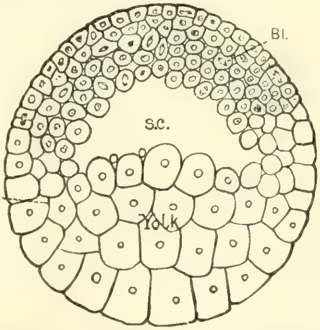

FIG. 501.—Egg of Axolotl after Segmentation. Transverse section. *Bl*, Primitive or ectodermal blastoderm; *s.c.*, segmentation cavity; *kw*, (Keimwall) germinal wall; *Yolk*, segmented yolk. (After Bellonci.)

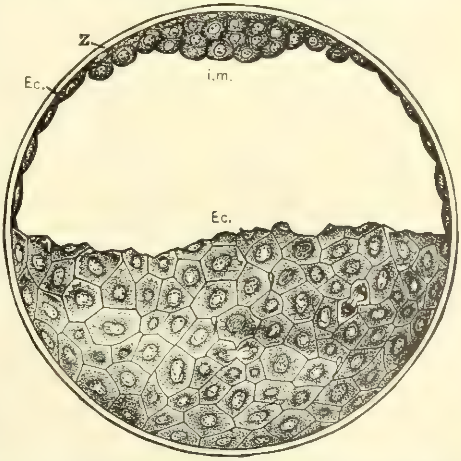

FIG. 502.—Ovum of Rabbit; ninety-four hours after coitus. *Ec*, External cell layer; *i.m.*, inner mass of cells; *Z*, zona pellucida. (The upper half represents an optical section, the lower half a surface view.) (After Van Beneden.)

from which it has slightly withdrawn, notably at the upper pole, where lies the thick cap of cells constituting the blastoderm, *Bl;* in the stage represented the outer layer of cells is just becoming marked off as a distinct layer, the ectoderm; underneath the blastoderm is the well-marked segmentation cavity, *s.c.;* everywhere at the edge of the blastoderm lies the segmenting zone, *kw.*, a ring of granular protoplasm with rapidly dividing nuclei; the cells resulting from these divisions are added to the edge of the blastoderm, which thus enlarges by peripheral additions as well as by the proliferation of its component cells. The segmenting zone is prolonged inward, forming the floor of the segmentation cavity, or, as it is named, the subgerminal plate, *s.g.* This plate grows in from the periphery toward the centre; it contains nuclei and thins out from the edge of the blastoderm inward. The segmenting zone, *kw.*, is essentially the homologue of the germinal wall of the amniota, which has been described under *Area*, but it is sharply bounded against the yolk, and in that respect differs from the wall in the chick, because in the latter the germinal wall merges gradually into the yolk.

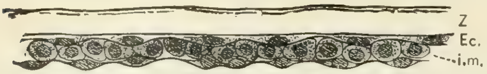

Fig. 503.—Section of Rabbit's Blastoderm, of five days and four hours. *Z*, Zona pellucida; *Ec*, ectoderm; *i.m.*, inner mass. (After Van Beneden.)

In the ovum of elasmobranchs (sharks, etc.), we find, at the so-called close of segmentation, that the blastoderm is a lenticular mass of cells, a little thickened at one point where the primitive streak arises later, and resting at its edge upon the very large yolk, which forms an encircling zone of segmentation around the blastoderm; between the mass of cells and the yolk there is a cavity commonly described as the segmentation cavity. If this designation be correct, then the comparison with the teleost ovum is direct and evident. It is possible, however, that the space under the blastoderm is not the true segmentation cavity, but the entodermic cavity, as maintained by Balfour; in other words, that the disposition of parts is the same as in the birds, which we proceed to describe.

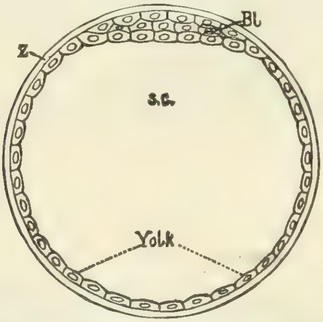

Fig. 504. Diagram of a Segmented Mammalian Ovum. *Bl*, Blastoderm; *s.c.*, secondary cavity of the yolk; *Yolk*, layer of cells, representing the remnant of segmented yolk.

The birds and reptiles being very closely related, we find very close resemblances between the blastoderms in the two classes. The actual homologies of the parts have been worked out as yet only in the birds, but there cannot be much doubt that essentially the same features exist in the blastoderm of reptiles. Duval has recently shown that in birds the primitive blastoderm represents only the ectoderm, as is the case also with the amphibia; it is separated from the underlying yolk by a distinct cavity; in birds this cavity is very small, and is overlaid by a single row of cells, the ectodermal or primitive blastoderm; the cavity is very soon obliterated by the development of cells below it, and these cells, together with the outer layer first formed, constitute the secondary blastoderm, which, therefore, contains, first, the young ectoderm, and, second, a deeper-lying stratum of cells, shown by their subsequent history to be the mesoderm united with part of the entoderm; in other words, at this stage the mesoderm and entoderm are not distinct. Underneath this compound blastoderm appears a second cavity, which is not what it has been often called—the true segmentation cavity—but is entodermic, being bounded by the true entoderm above and the yolk below; the yolk, it must be remembered, is modified entoderm. In birds (and probably reptiles) the thick blastoderm of the teleost is represented by only a few cells; the secondary blastoderm is another structure, consisting of two layers, and developed later.

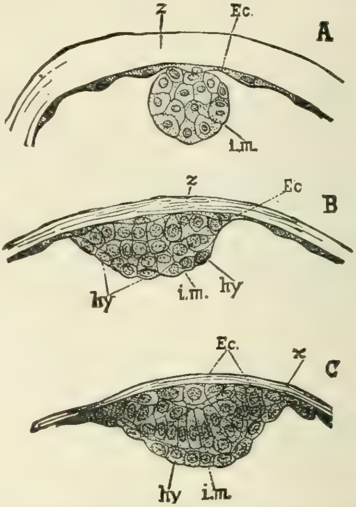

Fig. 505.—Sections through Three Successive Stages, Ovum of the Mole, to show the changes in the inner mass, *i.m.* *z* and *x* designate the zone pellucida; *Ec*, subzonal cell layer, usually called ectoderm, but probably entoderm; *hy*, portion of the inner mass, which enters into the composition of the entoderm of later stages. (After Heape.)

The similarity between the eggs of ganoids and of amphibians permits us to consider these two classes together. At first sight the segmented ovum of an amphibian seems very unlike that of the mesoblastic vertebrates, but if we begin by the study of parts obviously identical, I believe that we can determine the homologies of all the parts. Fig. 501 represents a transverse section of an ovum of an axolotl; the membranes of the ovum are not represented. The parts can be readily compared with those in the teleost. The blastoderm, *Bl*, is very large in proportion to the whole ovum, and is composed of several layers of cells, all of which belong to the ectoderm, and at this stage are found to be multiplying with extreme rapidity; the yolk is segmented, and accordingly consists of large cells. At the edge of the yolk, *kw*, is the zone in which cells are being added to the blastoderm, and which is therefore the homologue of the germinal wall. The segmentation cavity, *s.c.*, is very large; the yolk cells bounding it inferiorly may, perhaps, be homologous with the nucleated subgerminal plate of teleosts. The segmentation cavity is ultimately obliterated, and a secondary blastoderm, including the three germ layers, is developed, as described in the article *Fœtus, Development of.* Underneath the secondary blastoderm arises a second distinct, or true entodermic cavity (Fig. 506). The relations are strictly comparable, therefore, to those in the birds.

The mammalia, according to the description hitherto given, offer no homology in the blastoderm stage with other vertebrates. The formation of the blastoderm is described under *Segmentation.* The result of segmentation is the so-called blastodermic vesicle, a hollow sac formed by a single layer of cells (Fig. 502, *Ec.*) lying close against the zona pellucida; at one pole, where the embryo is subsequently formed, lies a lenticular mass of cells, *i.m.* Now, the exact relations of this cell mass have never been thoroughly studied by any one with the view of elucidating the homologies of the parts, all investigators having apparently come to a tacit agreement to neglect this problem. Van Beneden, to be sure, attempted an interpretation by calling the outer vesicle the ectoderm, and the inner mass the invaginated entoderm, thus defining the whole as a modified gastrula. It has since been definitely settled that Van Beneden was in error in this. Our knowledge of the changes that take place in the inner cell mass is based almost wholly upon the study of various rodents (rabbits, guinea-pigs, and mice), all of whom pass, during their early development, through phases which obviously represent great modifications of the normal mammalian ontogeny. In the rabbit the cells where the inner mass lies soon form three layers (Fig. 503). These are not, however, the three germ layers; for, as Rauber has shown, the two outer layers form the ectoderm, and the third inner layer forms the entoderm; the mesoderm arises later. Here, then, we reach a definite point of comparison. The whole of this mass of cells performs the rôle of the secondary blastoderm in the chick, teleost, and frog; I therefore conclude that it is the mammalian blastoderm. The second point to be made is that the so-called cavity of the blastodermic vesicle is probably not the segmentation cavity, but the secondary yolk cavity, which later fuses with the notochordal canal (see *Notochord*) to form the definitive archenteron. Hence comes the third point, that the cellular vesicle represents not the ectoderm, as has hitherto been universally assumed, but the yolk sac hollowed out.

For convenience of comparison with Figs. 500 and 502, the accompanying diagram (Fig. 504) of a mammalian ovum after segmentation is given. According to the identification of homologies I have here hypothetically advanced, the blastoderm, *Bl*, must include both ectoderm above and entoderm within. If we imagine the yolk of the axolotl, Fig. 501, very much reduced, so as to form only a single layer of cells, we should have the mammalian condition, Fig. 504.

It appears to me that the invagination of the inner cell mass is a general phenomenon in the development of placental mammals, and that the remarkable inversion of the germ layers in the guinea-pig is only a persistence of this early invagination. It is a law which, as I pointed out several years ago, holds throughout the animal kingdom, that the result of segmentation is to produce two sets of cells: one of small-sized cells, belonging to the ectoderm, the other of larger cells, belonging to the entoderm. In mammals also segmentation produces the two kinds of cells, but the smaller ones (ectoderm) form most of the inner cell mass which Van Beneden erroneously called entoderm. It seems to me clear that this first invagination has nothing to do with a gastrula invagination. The inner cell mass gradually flattens out again in most cases, but in some mammals it remains permanently turned in (guinea-pig, arvicola, etc.). The process of the flattening out of the inner cell mass is shown in Fig. 505, which represents sections. In the mole the inner mass is nearly globular, A, and quite small in proportion to the whole vesicle. It soon becomes lens-shaped, B, and next separated into three layers, C, the outermost of which disappears; the middle layer becomes the ectoderm of the embryo; the innermost, part of the entoderm. These changes are discussed in the article *Fœtus.* For the present it must be said that we have no clear notions as to the passage of the segmented mammalian ovum into the embryo, because we do not know yet either the history of the segmentation cavity nor the origin of the entodermic cavity.

Conclusions.—The blastoderm of (probably all) vertebrates passes through two stages: the *primary blastoderm* consists of ectoderm only, which is separated, except at its edges, from the yolk by the segmentation cavity; the *secondary blastoderm* is constituted by portions of the three primary germ layers, which overlie a second cavity belonging to the entoderm and lying behind and separated from the segmentation cavity; the secondary blastoderm is the commencement of the embryo.

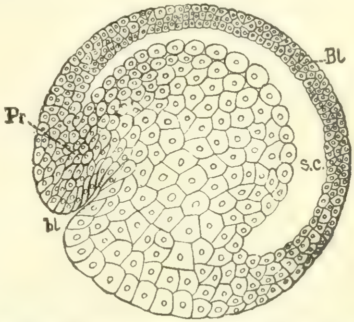

Fig. 506. Egg of Axolotl, Longitudinal Section. (After Bellonci.) *Bl*, Primitive blastoderm; *Pr*, accumulation of cells, showing the commencement of the secondary blastoderm; this accumulation corresponds to the primitive streak of birds; *bl*, blastopore and commencement of the entodermic cavity.

The history of the changes in the secondary blastoderm is given under *Fœtus.* We will note here only the nature of the first step, which is an accumulation of cells, appearing at the posterior end of the blastoderm, and which is known in the higher vertebrates by the name of *the primitive streak.* It is almost the first step toward the addition of inner layers to the ectoderm or primary blastoderm, and it remains recognizable for a considerable period at the hind region of the blastoderm or germinal area.

Charles Sedgwick Minot.

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BLASTOPORE.—In the lower vertebrates, notably in the Elasmobranchiata, Ganoidea, Dipnoe, and Amphibia, there appears during the formation of the entodermic cavity a small opening at the posterior edge of the blastoderm. This opening leads directly into the entodermic cavity, and is known as the blastopore. It persists during early embryonic life. This opening is best seen in a longitudinal section (Fig. 507). The blastoporic opening leads into a descending canal, which directly communicates with the posterior, or caudal, end of the entodermic space, which lies between the yolk, *Vi*, and the dorsal entoderm, *Ent*. The appearances of the ova of the lamprey, or of any amphibian, at a corresponding stage, are closely similar to those of Fig. 507.

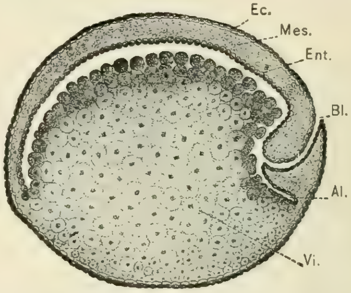

FIG. 507.—Longitudinal Section of an Ovum of the Sturgeon After the Formation of the Entodermic Cavity. *Ec*, ectoderm; *Mes*, mesoderm; *Ent*, entoderm; *Bl*, blastopore; *Al*, diverticulum of the digestive tract; *Vi*, yolk. (After Salensky.)

The blastopore is also found in reptiles, birds, and mammals, but the recognition of its occurrence in these forms was long hindered by the fact that it does not exist at first as a canal. The blastopore is the external opening of a tube passing through the primitive streak, or the thick mass of cells at the posterior end of the blastoderm (or later embryo). Now, if from any cause the walls of the tube grew together, the lumen would disappear, and the primitive streak would become a solid mass of cells. This is the condition we actually find in the mammals (Fig. 508, A). Now, since the primitive streak really is morphologically the thick wall of the

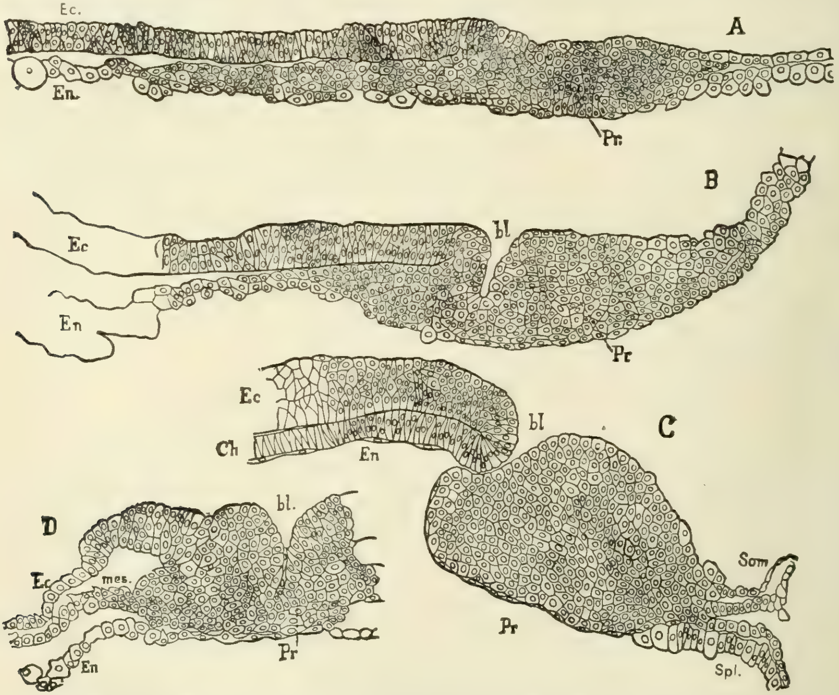

FIG. 508.—Formation of the Blastopore in Lacerta Muralis. (After Weldon.) A, B, C, longitudinal sections of three successive stages in the development of the blastoderm, made after its removal from the yolk; D, transverse section of the posterior part of a blastopore a little younger than C. *Ec*, ectoderm; *En*, entoderm; *Pr*, primitive streak; *bl*, blastopore; *Ch*, notochord; *mes*, mesoderm; *Som*, somatopleure; *Spl*, splanchnopleure.

blastopore, the homologies are not altered by the temporary disappearance of the canal, especially as the canal reappears as such in later stages, at first as a pit upon the external surface (Fig. 508, B, *bl*); this pit soon becomes a complete perforation (Fig. 508, C, *bl*).

It is a remarkable but very common phenomenon in vertebrate development to encounter tubular organs existing temporarily as solid cell masses in the embryo. This occurs with most glands, the Wolffian duct, the vagina of man, the urethra in the penis, the nares, the meatus auditorius externus, the posterior part of the medullary canal in the axolotl, the intestines of teleosts, etc. There is, therefore, nothing specially remarkable in the temporary absence of the blastoporic lumen, and the want of an opening is not a valid argument against the homology of the amniote blastopore with that of the amphibia and similar forms.

(For the relation of blastopore to the nervous system, see *Neurenteric Canal.*)

The blastopore usually disappears by closure, and a new posterior opening, the true or permanent anus, is formed. Miss Johnson states that in the Triton the anus is the persistent blastopore, an observation of great theoretical importance. *Charles Sedgwick Minot.*

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The literature of the blastopore is very extensive. The following list cites only a few of the most important articles; those by Balfour and Bellonci may be signalized as of especial value.

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BLENNOSTASINE is a compound of unstated formula derived from one of the cinchona alkaloids. It is sedative to the central nervous system and has given much relief in hay fever, coryza, laryngitis, etc. It is not applied locally, but is given by the mouth in doses of gr. i. to iv. frequently repeated. *W. A. Bastedo.*

BLEPHAROSPASM.—DEFINITION.—Spasmodic contraction of the orbicularis palpebrarum muscle, tonic or clonic in character, evidenced by occlusion of the palpebral fissure when the entire muscle is affected, or by fibrillary contraction of a limited portion.

It occurs generally as a symptomatic affection, although it can exist as a disease by itself.

Its causes may be divided into three groups: first, affections of the eye and ear; second, affections of the nervous system; third, general diseases. The first group includes foreign bodies in the conjunctiva or cornea, inflammations of the conjunctiva, cornea, iris and ciliary body, sympathetic irritation, ectropion, entropion, trichiasis, heterophoria, ametropia, foreign bodies in the external auditory canal, and otitis media.

The second group comprises affections of the facial and trigeminal nerves, hysteria, and chorea.

The third group includes as causes, chlorosis, pernicious anæmia, malaria, rheumatism, and influenza.

SYMPTOMS.—It occurs in the form of a tonic or of a clonic spasm. In the tonic form the palpebral fissure is tightly closed, great force often being required to open it. It is an excessive action of the normal reflex mechanism, often persisting as a troublesome affliction in excess of its cause. It may be intermittent in character, coming on suddenly, and frequently placing the patient in great danger, when it is binocular; or continuous, sometimes to such a degree as to cause a temporary amaurosis. The latter condition is usually observed in children of three or four years of age, after relief from a very protracted blepharospasm. They are unable to see large objects, and orientation is practically impossible. The pupillary reflex will be found active, strong light painful, and ophthalmoscopic examination negative. The amaurosis is believed to be cortical in nature (Leber, Uthoff), owing to the absence of peripheral stimulation. Samelsohn has considered it to be analogous to the suppression of the image in alternating strabismus. Others believe it to be due to the disturbance of the intra-ocular circulation by the prolonged pressure of the eyelids, in support of which belief they cite individual cases which have exhibited choroidal and retinal changes.

In clonic blepharospasm there are intermittent contractions of the entire muscle, manifested by constant opening and closing of the palpebral fissure, or by contractions of a limited number of fibres, as evidenced by a slight twitching of the lids, more often of the lower lid. While the spasm may be intermittent at the outset, its continuance engenders its becoming constant and permanent, and frequently the spasmodic impulse extends to neighboring muscles.

CAUSES.—Tonic spasm is particularly induced by foreign bodies in the conjunctiva and cornea, and by abrasions or inflammations of the conjunctiva and cornea, the phlyctenular variety particularly giving rise to it. This form of inflammation, which is seen in strumous children, is frequently accompanied by nasal disease, which may cause a persistence of the spasm long after the conjunctival and corneal disease has disappeared. The intense photophobia, and the œdema of the lids, particularly of the upper, caused by the compression of the veins of the lids by the firmly contracted muscle, render the examination of the eye extremely difficult. Fissures of the commissures and spastic ectropion or entropion are induced. It is believed that the blepharospasm in keratitis is due to direct irritation of the corneal nerves; Iwanoff having found that the cellular infiltration extended along the course of the corneal nerves. It is, however, in part voluntarily induced by the patient for the purpose of relieving the photophobia. The forcible separation of the lids is often accompanied by pain, sufficient in some cases to induce epileptiform convulsions, and by sneezing, reflex in character, caused by the hyperæsthesia of the retina to light. The violence of the spasm is by no means in direct proportion to the severity of the disease of the eye, slight corneal abrasions or a small foreign body frequently inducing the most violent tonic spasm. Iritis and cyclitis are occasionally accompanied by blepharospasm. Donders speaks of it occurring as a sympathetic neurosis in cases of irido-cyclitis. Rampoldi reports cases that were caused by the presence of foreign bodies in the external auditory canal, Ziem a case following syringing of the cavity of the tympanum, and Berger cases accompanying suppuration of the sinuses adjacent to the orbit.

Clonic blepharospasm is frequently observed in young children on their commencement of school life, either as a decided complete contraction of the muscle, or in the form of fibrillary twitchings, often difficult to discover on close inspection, though extremely annoying. In the first instance it is often a manifestation of commencing chorea, the children presenting a marked anæmia. The fibrillary form is generally due to uncorrected errors of refraction. Adults presenting heterophoria and ametropia, particularly hypermetropic astigmatism, are prone to this variety.

Affections of the facial nerve through traumatism or cerebral lesions may give rise to blepharospasm, though it is more often a reflex phenomenon due to a local or distal irritation of one of the branches of the trigeminus. Supra- and infra-orbital neuralgia, caries of the teeth or maxillæ, ulcerations of the tongue, mouth, and palate, and chronic affections of the lachrymal canal may be cited as causes of such irritation. Saemisch has mentioned cases which were caused by the imprisonment of sensitive nerve filaments in cicatrices. In neuralgia of the different branches of the fifth nerve sensitive points can be found, pressure upon which will often arrest the spasm. These spots may be situated at the point of exit of the nerves from their foramina, or may be located some distance from the affected muscle, as at the back of the neck, over the spines of the vertebræ. Romberg found that pressure upon the facial nerve at its exit from the stylo-mastoid foramen would arrest the spasm in some cases. The patient often discovers where these pressure points are situated, and will avail himself of this knowledge to obtain relief. Pressure upon certain parts of the body has been known to bring on blepharospasm, as in the case reported by Zehender, in which pressure in the region of the first cervical vertebra induced it. Cases like this one are undoubtedly of hysterical origin. Indeed, not a few cases of blepharospasm are of hysterical nature. The spasm may be caused primarily, in these subjects, by traumatism, by a carious tooth, or by a foreign body in the conjunctiva, cornea, auditory canal, etc. Its continuation after removal of the cause and disappearance of all irritation would indicate its hysterical character. It is usually binocular, tonic in character, and rarely preceded by clonic movements. Its disappearance is as sudden as its invasion, and its duration varies greatly. Dr. Charles Lasègue cites a case of monocular hysterical blepharospasm, caused by traumatism, which lasted four months, while the immediate effects of the traumatism lasted but twenty-four hours. A constant twitching of the upper lids repeated about twice a second is characteristic of hysteria, and is believed by Knies to be due, like nystagmus, to a weakening of the motor cortical innervation of the muscles. Anæsthesia of the palpebral skin may be noticed as an accompanying symptom, as shown by Gilles de la Tourette. In anæmic and nervous children blepharospasm occurs as the commencement of general chorea. The habit-chorea (Weir Mitchell), which commences in childhood, ceases after a few months or years, although it occasionally goes on to middle life. When it commences in middle life it is generally permanent. It is more common in females, following some impairment of the general health, fright, injury or overwork, and in boys, as the result of masturbation. Imitation can bring it on and observation increases it. Refractive errors, follicular conjunctivitis, and blepharitis are also found as frequent causes. It is often associated with symptoms of hysteria in young women, making it difficult to determine to which disease the spasm properly belongs. Anæmic women occasionally present a clonic monocular spasm, due to the general debility induced by uterine and ovarian disease.

Prognosis.—The prognosis in blepharospasm is uncertain except where it is due to hysteria, traumatism, conjunctival or corneal disease. Prolonged contraction may involve serious consequences to the eye, through the pressure of the lids causing definite lesions of the choroid or retina.

Treatment.—The treatment of blepharospasm resolves itself into treatment of its causative conditions. A careful search should be made for foreign bodies in the conjunctiva, cornea, nose, and ear. If conjunctivitis and keratitis, particularly of the phlyctenular variety, are present, they should be carefully treated. Cocaine, while often of value in relieving blepharospasm and rendering the examination of the eye easier, should be avoided in cases in which there are corneal ulcerations; holocain should be used instead, in one-per-cent. solution. The dilatation of the pupil with consequent increase of the photophobia, owing to the hyperæsthesia of the retina and the softening of the corneal epithelium following the use of the cocaine, are avoided by the substitution of the holocain, the latter being primarily an anæsthetic and secondarily an antiseptic. In cases in which the spasm persists after the conjunctival and corneal disease has been cured, forcible opening of the palpebral fissure, during chloroformization, with canthotomy if necessary, and the dropping of iced water on the exposed eyeball at half-hour intervals, will usually suffice to produce a cure. These children should not be allowed to remain in the dark, nor should dark glasses be given. Fissures of the canthi may be touched with a crystal of sulphate of copper or with nitrate of silver, and the accompanying nasal disease, when present, should be treated. In cases in which eserin is seemingly indicated it may be found that the spasm is increased by its use, eserin having been known to cause violent blepharospasm. De Wecker recommends its use as a curative agent, believing that it diminishes the tendency to reflex transmissions. Errors of refraction must be corrected under atropinization, and muscular errors should be carefully remedied. In cases due to irritation of some branch of the fifth nerve, careful search must be made for pressure points. Hypodermic injections of morphine, in doses of from gr. $\frac{1}{16}$ to $\frac{1}{8}$, may be made at these points. Conium, in the form of the fluid extract, may be given in doses of ten drops, from three to six times daily, until the physiological effects of the drug are shown. The extract of conium may at the same time be used externally in the form of an ointment. Gelsemium may be found of benefit in the cases of true tic doloureux. Galvanism, used after the method of Remak, the negative pole being applied over the muscle and the positive over the fifth cervical vertebra, is sometimes efficacious.

The careful examination of the mouth and teeth by a competent dentist should always be insisted on, the patient often being unaware of the presence of dental or buccal trouble. Other remedies having failed, and pressure upon sensitive points having been found to give relief, division of the offending nerve may be practised. This operation was first performed by von Graefe in a case following the lodgment of a foreign body in the folds of the conjunctiva. The nerve divided was the supra-orbital, and success followed the operation. The supra- and infra-orbital nerves should be divided at their exit from their respective foramina, the temporal branch of the malar in the temporal fossa, and the inferior dental in the mouth. The nerve should be completely cut through; in fact, some authorities think that a better result is obtainable by the excision of 1 to 2 cm. of the nerve. The relief given by section of the nerves is not always permanent, the spasm after a short period returning and being accompanied by the development of new pressure points. This is particularly true in senile blepharospasm. Excision of a portion of the nerve is productive of more lasting relief, although it gives rise to a prolonged anæsthesia of the region supplied by the nerve. Stretching of the nerves has been advocated by Panas. Dieffenbach practised subcutaneous division of the orbicularis muscle, but without much success.

Treatment of hysterical blepharospasm is decidedly unsatisfactory. Tonics, sea bathing, the use of the appliance devised by Mathewson and used with success by Strawbridge, and the application of the Charcot magnet with suggestion, may be tried. The device of Mathewson consists of a rubber band fastened to the upper lid below, and to the forehead above. The constant traction eventually overcomes the resistance offered by the muscle. Arsenic given internally, or hypodermically, as suggested by Weir Mitchell, appears to be the most efficacious remedy in the cases of habit-chorea.

C. Cole Bradley.

BLINDNESS.—(Lat., *Cæcitas;* Ger., *Blindheit;* Fr., *Aveuglement.*) *Amaurosis* is sometimes used synonymously with blindness, and in selected cases—the cause of which is obscure, or is located in the nervous apparatus—this is admissible, with the same limitations that apply to blindness. Blindness is a misleading term, being a symptom only, and should not be used in scientific language (except in a generic sense) without a qualifying phrase which describes the condition upon which it depends—as blindness from optic-nerve atrophy. A strict application of the term would include only such eyes as are not possessed of light perception. It is, however, usually understood to embrace all eyes incapable of recognizing the outline or shape of objects; and practically it should include all eyes with vision less than $\frac{1}{200}$, *i.e.*, all eyes which are able to count fingers at only one foot, for such individuals have to be *led* around.

ECONOMIC EFFECTS OF BLINDNESS.—Blindness is a misfortune not only to the individual, but to a community, for a blind person has to be *supported*, and, too, he is not a *producer*. To illustrate the importance of these two factors, let us apply them to the United States, which, according to the census of 1890, had 50,411 blind inhabitants. The *cost* of supporting one blind person in an economical manner may be placed at $132 annually ($2 per week for board, $28 for clothing), so that the *cost* to this country for caring for its blind is $6,654,252 annually. The *producing* capacity of a man at $1.20 for each working day and of a woman at $0.40 a day would be $404 and $256 respectively annually, which would give $17,024,480 as the annual earning capacity lost to this country by its blind—cost and loss together amounting to $23,678,732.

The GEOGRAPHICAL DISTRIBUTION of blindness as shown in Table I., compiled by Mayr, of Munich, in 1877, has been subject to slight changes by later statistics, so far as the proportion of the blind to the population is concerned.

TABLE I.

Country.	Population.	Total number of blind.	Number of blind in 10,000.
England and Ireland	31,631,212	31,159	9.85
Denmark	1,864,496	1,465	7.86
Norway	1,701,756	2,320	13.63
Sweden	4,168,525	3,359	8.06
Finland	1,732,621	3,891	22.46
Austria	20,394,980	11,329	5.55
Hungary	15,417,327	18,523	12.01
Switzerland	2,669,147	2,032	7.61
Netherlands	3,575,080	1,593	4.46
Belgium	4,529,560	3,675	8.11
France	36,102,921	30,214	8.37
Spain	15,658,531	17,379	11.26
Italy	26,413,132	26,826	10.16
United States of America	38,558,371	20,320	5.27
Argentine Republic	1,743,199	3,529	20.24
British colonies in—			
North America	583,535	361	6.19
West Indies	905,730	2,030	22.41
Africa	330,460	416	12.53
Australia	305,730	116	3.79
Germany	39,862,133	35,048	8.79
Totals	248,148,446	215,585	8.74

The population of the United States in the above table is taken from the census of 1870. The census for 1880 shows a population of 50,155,783; number of blind, 48,928; number of blind in ten thousand, 9.73. A striking difference is the great increase of blindness in the United States in the subsequent decade, as is shown in the figures for 1880. Various causes must be considered in determining the reasons for this increase in blindness, the most important of which are the following: 1. The census returns were more complete for the last census than they have been heretofore. 2. Injuries more or less remote from the eye, sustained during the late war, continue to swell the ranks of the blind, and with pensions in view a considerable number make the claim unjustly. 3. The foreign element in our population adds to the percentage of blind; for natives of the United States furnish 9.13 blind to 10,000 inhabitants, while 13.45 blind are found in the same number of our foreign population. 4. The increase of manufacturing interest and its spread to localities remote from competent professional care. 5. The increase of those competitive trades that bring bodily and mental strain, which are liable to produce changes in the nervous system, in which the eyes participate.

The last decade—census for 1890—shows a gratifying reduction in the proportion of blindness: population, 62,622,250; blind, 50,411; number of blind in 10,000, 8.1; number of natives blind in 10,000, 7.4; number of foreigners blind in 10,000, 10.1. This improvement is due to two causes: first, the proportion furnished by the late war has been depleted by death, and the proportion of foreigners has been lessened by laws restricting emigration; second, people are being educated to seek proper relief for diseases and injuries of the eyes.

The latest foreign statistics, as obtained from Eulenburg's *Real-Encyclopädie*, p. 502 (1894), show the number of blind to 100,000 inhabitants of the countries referred to, as follows:

TABLE II.

Holland	44	Prussia	83	Norway	134
Canada	62	France	84	Spain	148
Poland	70	Germany	85	Caucasia	150
Italy	75	England	88	Argentina	202
Switzerland	76	Austria	94	European Russia	210
Denmark	79	United States	97	Finland	211
Sweden	80	Ireland	120	Portugal	219
Belgium	81	Hungary	128	Iceland	340

The statistics in Prussia, according to Guttstadt, show that in 1871 there were 22,977 blind—*i.e.*, 9.5 per 10,000—whilst in 1880 there were 22,678, or 8.2 to 10,000. This shows a diminution of 1.3 per 10,000, although the population had increased 10.6 per cent. In Saxony the figures declined from 7.9 to 7.1.

The latest blind census in Austria, on December 31, 1890, showed 81 blind to 100,000, there being 907 females to 1,000 males.

The CLIMATIC INFLUENCE, as illustrated in Europe, is shown in Table III., from Magnus, of Breslau, 1883.

TABLE III.

Between latitudes 30° and 40° the number of blind in 10,000 is 11.09
" " 40 " 50 " " " " " 10,000 " 8.63
" " 50 " 60 " " " " " 10,000 " 7.55
" " 60 " 70 " " " " " 10,000 " 18.04

It is true also of the United States that the proportion of blindness gradually increases from the north to the south. The proportion of blindness is greatest in the Eastern portion of the United States, less in the middle, and least in the Western.

And for the Western continent the same author gives Table IV.

TABLE IV.

Between latitudes 10° and 20° the number of blind in 10,000 is 22.41
" " 20 " 30 (vacant).
" " 30 " 40 the number of blind in 10,000 is 8.96
" " 40 " 50 " " " " " 10,000 " 5.36

The hot southern latitudes are injurious, because of their dry, sandy interiors (in which the glare and the prevalence of high winds, accompanied by clouds of a fine sandy dust, exert an irritating influence upon the eyes), and their moist, swampy, miasmatic borders and water-courses. The cold northern latitudes are injurious, because confinement in badly ventilated quarters is a necessary concomitant; and, the days being short during the long winters, the work of the eyes is crowded into a limited time, or is prolonged in insufficiently lighted rooms, where work becomes injurious. The most temperate zone presents the least number of these objections, hence we find here the smallest percentage of blindness. There are also geological causes which influence the percentage of blindness; for instance, it is more frequent on one side of the Jura Mountains than on the other.

It has been asserted that blindness was more frequent in cities than in rural districts, and this, aside from such causes as lead to blindness from injuries, trades, etc.; but investigations in Russia, and by Howe in this country, would seem to refute that claim under the present existing circumstances. Investigation of the number of blind in cities of the United States containing fifty thousand and upward inhabitants showed that the proportion was thirty-three per cent. less than in the country; and still further investigation by Howe seemed to show that this improvement was due to the more general use of preventive measures against ophthalmia neonatorum in cities than by the country practitioners.

That there are RACE PECULIARITIES is shown by the fact that out of 10,000 Christians there are only 9.4 blind, while the same number of Jews furnishes 13.3 blind. One reason for this large percentage of blindness in Jews is the great frequency with which they suffer from glaucoma. It is said that the sclera is more dense and less elastic in people of this race than in others, and that this condition favors the development of glaucoma. It has been further claimed that dark eyes are more prone to amaurotic affections than light ones, and that Jews, who usually have dark eyes, are therefore more liable to suffer from blindness. This, however, is not borne out by facts, for dark races are usually possessed of deeply pigmented eyes, yet the percentage of blindness is not great with them. It should be remembered, however, that the so-called amaurotic affections constitute but a small proportion of the causes of blindness; and the fact should not be overlooked that overcrowding and bad ventilation are often found in the class to which the majority of Jews belong—and such surroundings are prolific sources of external inflammations of the eye. Consanguinity in marriage is another cause which renders the Jewish race more prone to blindness than others. They, too, almost invariably live in cities, where the percentage of blindness has heretofore been higher than in rural districts. The number of blind negroes in the United States in 1890 was 7,160 out of a population of 7,470,040; or 9.5 to 10,000. Lack of care for diseases and injuries is the probable cause of much blindness with them, rather than any other racial difference.

INFLUENCE OF SEX.—The United States has a population of 32,067,880 males and 30,554,370 females, which gives a preponderance of 1,513,510 in favor of males. The number of blind males is 27,983, and of females 22,428, which gives a preponderance of 5,555 in favor of the male blind. The number of blind in 10,000 males is 8.7 and in the same number of females 7.3. This difference is a slight one, and can be easily accounted for by the accidents arising from exposure of the eyes to the injurious influences of the trades followed by men. An interesting fact bearing upon this point is the comparative diminution in the percentage of blindness in males after they reach an age which recalls them from pursuits that endanger the eyes to surroundings more nearly like those of females. Table V., prepared by Magnus from the Prussian census, illustrates this condition most aptly.

TABLE V.

Age.	NUMBER OF BLIND, 1871.		NUMBER OF BLIND, 1880.	
	Males.	Females.	Males.	Females.
Under 10 years....	664	558	572	488
10 to 20 years	1,113	845	992	823
20 to 50 years	2,572	3,336	3,565	2,989
Over 50 years	5,752	7,100	6,148	6,975

See in this connection Table X. for the causes which produce blindness at different ages.

TABLE VI.

Age.	Percentage of blind between the ages given.	Percentage of population.	Number of blind in 10,000.
1 to 10 years	3.7	24.9	1.75
10 to 20 years........	4.6	19.9	2.36
20 to 30 years	9.8	16.4	3.25
30 to 40 years	11.1	13.0	3.81
40 to 50 years......	15.2	11.1	6.84
50 to 60 years....	17.3	7.5	11.50
60 to 70 years..	19.7	4.7	26.23
70 to 80 years	13.5	1.8	92.44
80 to 90 years..	4.3	.3	207.00
90 to 100 years	.27	.02	373.20

Table VI. gives the percentage of blind *of* different ages in column 2, and the percentage of population *at* different ages in column 3 (Katz), while column 4, which has been adapted from Meyr's table, shows the number of blind in 10,000 *at* different ages.

This table, which is a very interesting and instructive one, deserves attention for its own merits; yet it becomes more instructive when considered in connection with Table X., which gives the causes that produce blindness at different ages.

The following table from Eulenburg's *Real-Encyclopädie*, p. 505 (1894), shows the percentage of blindness at different ages in the countries referred to, as follows:

TABLE VII.

Ages.	Thirteen German States.	England, Wales, and Ireland.	Finland.	Netherlands.	Belgium.	United States.
1 to 5...........	1.45	1.61	1.70	0.69	0.47	0.58
6 to 10..... ...	2.63	2.30	2.39	1.00	.79	1.66
11 to 15....	2.42	3.23	3.21	.98	1.60	2.75
16 to 20....... ..	3.73	3.76	4.30	1.92	1.87	3.38
21 to 30....	4.40	5.12	17.00	1.93	3.19	3.30
31 to 40....	6.41	7.81	12.52	2.95	5.51	4.17
41 to 50...........	9.90	10.95	126.31	4.31	14.11	6.55
Over 50	33.18	37.39	103.49	16.59	25.85	23.73
Not stated........	50.82	13.27	19.31	12.76	....	13.56

INFLUENCE OF OCCUPATION.—The causes of blindness incidental to occupation may be divided into two classes, viz., *traumatic* and *non-traumatic*.

Traumatic.—Under this head are included such occupations as necessitate exposure of the eyes to the direct influence of injurious agents from without, which result from the work performed—as machinists, who are constantly exposed to flying bits of metal, which often produce injury of the eye and blindness; and the same is true of blacksmiths, locksmiths, stone-cutters, and miners. The last named are also exposed to the dangers of premature or careless explosions. Cases of *monocular blindness* almost invariably arise from the causes just considered.

Cohn found 535 men with 554 blind eyes, and 241 women with 446 blind eyes. Preference is shown for neither eye. The United States census reports for 1890 show 93,988 cases of monocular blindness—or 15.1 to 10,000. The males show 21.7 to 10,000; females, 8.3 to 10,000. The greater frequency of binocular blindness in females is another argument in favor of the accidental occurrence of blindness from the injurious trades followed by men.

Non-traumatic.—Under this head are included such occupations as produce blindness indirectly—as myopia, from over-use of the eyes. Professional men, whose duties necessitate much study; and others, who, from necessity or preference, do much reading, or much fine work, which requires close and long-continued use of the eyes, are liable to suffer from myopia and the train of symptoms which in this disease lead to blindness. Workers in lead are liable to suffer from neuro-retinitis or atrophy of the optic nerves; and workers in India rubber are exposed to the same dangers, from sulphide of carbon. It is claimed that optic-nerve atrophy sometimes occurs in workers who are exposed to the fumes of tobacco or of alcohol. Soldiers in crowded barracks are apt to suffer from conjunctival diseases, and the exposure to wind, dust, glare, and inclemencies of weather, when marching, may also cause the same trouble. Sailors who are constantly exposed to the vicissitudes of weather are liable to suffer from conjunctival and other forms of eye disease, and their crowded quarters and often meagre fare are also conducive to eye affections.

CAUSES OF BLINDNESS.—Table VIII. gives an *anatomical* grouping of the causes of blindness, compiled by Magnus from 770 cases.

TABLE VIII.

	Per cent.
Conjunctiva	16.364
Cornea	10.650
Uveal nerve	22.208
Retina	16.259
Optic nerve	22.597
Glaucoma	12.597
Congenital deformities of the eye	2.468
Unclassifiable	2.857

Table IX., compiled by the same author from a study of 2,528 cases reported by various writers, gives the causes of blindness, arranged in *pathological* groups, and the percentage of each individual cause.

TABLE IX.

A.—*Congenital blindness.*	Per cent.
Anophthalmus and microphthalmus	1.068
Megalophthalmus	.435
Congenital cataract	.119
Choroiditis, congenital	.158
Atrophy of optic nerve, congenital	.751
Retinitis pigmentosa congenitalis	.751
Congenital blindness with retinal atrophy	.079
" tumors	.039
" amaurosis, not specified	.237
B.—*Acquired blindness*—(*a*) From idiopathic diseases of the eye.	
Ophthalmia neonatorum	10.876
Trachoma and blenorrhœa of adults	9.492
Diphtheritic conjunctivitis	.356
Diseases of the cornea	8.068
Irido-choroiditis, cyclitis, iritis	8.860
Choroiditis myopica	.949
Choroiditis, choroido-retinitis	1.107
Retinitis pigmentosa, acquired	1.266
Retinitis apoplectica	.119
Neuroretinitis	.791
Detachment of retina	4.746
Glaucoma	8.978
Idiopathic optic-nerve atrophy	7.751
Tumors of the eye and its surroundings	.356
Unclassifiable	3.368
C.—*Acquired blindness*—(*b*) Injuries.	
Direct injury of the eye	4.034
Unsuccessful operations	1.938
Injuries of head	.277
Traumatic sympathetic ophthalmia	4.509
D.—*Acquired blindness*—(*c*) The eye disease being in consequence of disease of the body.	
Diseases of the eye from syphilis	.470
Gonorrhœal conjunctivitis	.910
Scrofulous diseases of the eye	.039
Irido-choroiditis with meningitis	1.424
Atrophy of optic nerve, cerebral	6.961
" " " " spinal	2.333
" " " " of neuritis following hæmatemesis	.396
" " " " after vomiting, not blood	.079
Atrophy from hemorrhage from piles	.039
" after facial erysipelas	.079
" with insanity	.039
" " epilepsy	.158
" " dysentery	.079
Retinitis nephritica	.198
Diseases of the eye from typhus	.949
" " " " measles	.633
" " " " scarlatina	.514
" " " " variola	2.216
" " " " exanthemata (?)	.235
" " " " heart disease	.039
" " " " childbirth and pregnancy	.431
Intoxication amaurosis	.039
Blindness from disease of the orbit	.039

Congenital anomalies constitute nearly four per cent. of the causes of blindness. The majority of instances occur as a result of consanguineous marriages, or where there is an hereditary tendency toward defects of the eye, or as a result of syphilitic manifestations in intra-uterine life. They are usually hopeless—cataract being the only cause in this category which is amenable to treatment. Among 34 children, the offspring of 14 marriages in which one or both parties were blind from birth or childhood, Magnus found 8 cases, *i.e.*, 23.5 per cent., of blindness or bad sight.

The various ages at which other causes of blindness arise are well shown in Table X. from Magnus, which gives the percentage of causes at the ages when they are developed.

TABLE X.

Cause of blindness.	PROPORTION OF BLINDNESS IN 10,000, AND THE PERCENTAGE OF ITS CAUSES AT DIFFERENT AGES.										
	1 to 5 years.	6 to 10 years.	11 to 15 years.	16 to 20 years.	21 to 25 years.	26 to 30 years.	31 to 40 years.	41 to 50 years.	51 to 60 years.	61 to 70 years.	71 to 80 years.
Ophthalmia neonatorum	1.99										
Trachoma	...	0.04	....	....	....	. .	. . .	0.07	0.02	0.05	0.12
Injuries	.01	.04	0.02	0.05	0.10	0.21	0.13	.19	.05		
Optic-nerve atrophy of all forms.	.35	.26	27	.26	.30	.28	.69	.61	.47	.26	.12
Uveal tract with choroido-retinitis, retinitis pigmentosa	.27	.11	9.14	.13	.27	.28	.25	.29	.32	.49	.12
Detachment of retina	.01	.04	.07	.05	.20	.24	.11	.14	.29	.10	
Glaucoma	....	....	..		....		.07	27	.65	1 50	1 30
Operations	.	....	....	....			.01	....	.05	....	.25
Corneal diseases	.27	.04	.04	.02	.13	.14	.05	.04	.14	.10	
Variola	.13	.04	. .	.02	....	....	....	.02			
Measles	.13										
Scarlatina	.07	.04									
Typhus	.01	.04	07	.15	.03	.03					

The various causes of blindness, as given in Table IX., will now be considered individually, with such remarks and deductions as are of general interest.

(1) *Ophthalmia neonatorum* furnishes 10.876 per cent. of the blind, a larger proportion than any other single cause—which in itself invests it with grave importance; and this importance is greatly enhanced when it is considered that blindness from this cause means an entire life of blindness; that this disease can be practically prevented by proper prophylactic measures; and further, that even after it is developed, prompt, energetic, and appropriate treatment will usually bring it to a successful termination without impairment of sight. The simple measure of washing the eyes of all infants with warm water as soon as they are born, and instilling a few drops of a two-per-cent. solution of silver nitrate into the conjunctival sac, and subsequent attention to cleanliness, would almost banish this disease from our lists, as has been lately proven in the Maternity Hospital in Vienna and other similar institutions. Ophthalmia neonatorum is almost always caused by the irritating discharges from the vagina, which gain access to the eye either during birth, or, later, by the careless handling of the infant with unwashed hands which have been about the vulva. And it should be borne in mind that these discharges may produce inflammation in any conjunctiva with which they come in contact. Furthermore, the contagiousness of conjunctival discharges should never be overlooked, and this action should always be explained to those who have to deal with any form of conjunctivitis. As a rule, the contagious material from a mild form of conjunctivitis will produce a slight attack in another eye, and *vice versâ* for virulent forms. Yet this is not always the case.

(2) *Trachoma and blennorrhœa of adults,* with a percentage of 9.492, come next in order of importance. *Trachoma* occurs chiefly in the lower walks of life, where, from necessity or indifference, there are overcrowding, bad ventilation, lack of cleanliness, and a general disregard of the laws of hygiene. It is often seen in the poor and neglected of our city population, in the crowded barracks of military camps, and in the confined quarters of northern latitudes. Its development is favored by low and damp localities on the one hand, and by dry and sandy districts on the other. The contagiousness of the secretion is also an important element in the spread of the disease in crowded quarters. The presence of trachoma, even in a mild form, renders an eye very prone to take on an active form of inflammation (blennorrhœa), which will assume epidemic character if conditions favor its spread, as is seen in Egyptian or military ophthalmia. Once developed, trachoma becomes always an obstinate, and often a serious, disease; hence prophylactic measures

against it are of the utmost importance, and they are to be found in a correction of the sanitary conditions referred to. Its local treatment should be prompt, energetic, and persistent.

Blennorrhœa of adults may arise from the same conditions that produce trachoma, and it is often an outgrowth of the latter. It is frequently—in fact usually—the result of contagion. The discharge from any form of conjunctivitis, as also leucorrhœal or other irritative discharges, gaining access to the eye may produce the disease. The observance of care and cleanliness, with proper regard to hygiene, would cause both of these diseases to disappear, and appropriate treatment would cure most cases, even after the disease has developed.

(3) *Diphtheritic Conjunctivitis.*—Diphtheritic and membranous ophthalmia are sometimes caused by direct infection of the conjunctiva by diphtheritic material from the throat of another person, while in other cases the diphtheritic process creeps up the nasal duct from the nose, and thus reaches the lining membrane of the eye. But in the majority of cases of diphtheritic ophthalmia the disease is a local one, in which the inflammation takes on this special form. No doubt there is often something peculiar in the patient's health, or in the state of his eye tissues, which gives a proclivity to this particular pathological process. These cases are, for instance, seen with particular frequency after measles, and less commonly during or after scarlet fever, and are more likely to occur in children than in adults. The existence of old, granular disease of the conjunctiva also gives a strong tendency to a diphtheritic type of inflammation, and the same tendency is seen sometimes in a well-marked degree in ophthalmia neonatorum, and in gonorrhœal ophthalmia.

(4) *Diseases of the Cornea.*—This furnishes rather a large contingent of blind, and it is not to be wondered at when we consider that transparency and regularity of curve of this membrane are essential to good vision. Keratitis, in its various forms, may leave opacity sufficient to cause blindness; and the same is true of superficial ulceration; while deeper ulceration may lead to prolapse of the iris, displacement or obliteration of the pupil, etc., and all are at times liable to be followed by softening of the cornea, with development of staphyloma, etc. Hypopyon keratitis furnishes a larger number of blind than all other corneal affections put together. Kerato-conus and kerato-globus are sometimes causes of blindness.

(5) *Irido-choroiditis, Cyclitis, Iritis.*—The different diseases enumerated under this heading are placed together, first, because they often combine; and, second, because the structure involved—the uveal tract—is common to each of the several anatomical parts designated. The term *uveitis* is often and advantageously employed to describe, collectively, inflammations in these parts. *Iritis*, uncomplicated, rarely causes blindness; yet it may do so if the pupil becomes glued down to the lens and the pupillary space becomes blocked with exudation (*occlusion of pupil*). Both this condition and that of *exclusion of pupil* (complete posterior synechiæ) are very apt to be followed by *secondary glaucoma*. More frequently synechiæ from previous inflammation cause recurrent attacks of iritis; and the inflammatory process, extending to the choroid, or to the ciliary body, or to both, gives rise to opacities in the vitreous, and later to detachment of the retina, cataract, etc. The trouble may begin in the choroid, or, less frequently, in the ciliary body, and, extending to other parts or remaining in either locality, may cause blindness in the same way.

(6) *Choroiditis myopica* (6) *and detachment of the retina* (11) will be treated of together under the head of the latter, both being considered as effects of myopia.

(7) *Choroiditis, Retino-choroiditis.*—The choroid and retina are so intimately associated that it is difficult to have an affection of one of these structures without involvement of the other. Syphilis, acquired or inherited, is the usual cause; and blindness is produced by the formation of opacities in the vitreous and disturbance or destruction of the retinal elements.

(8) *Retinitis Pigmentosa, Acquired.*—Though this affection may be developed at almost any period of life, it cannot be considered an acquired disease, for it occurs in particular groups of individuals who, from hereditary tendencies or from consanguineous marriages, show congenital deficiencies in this and in other ways. Such cases are hopeless; and even when the disease is recognized in an early stage little or nothing can be accomplished in the way of treatment.

(9) *Retinitis Apoplectica.*—The chief significance of this disease is the index which it furnishes of the condition of the blood-vessels in the brain; for it is usually but a precursor of similar trouble within the cranium.

(10) *Neuro-retinitis*, as an idiopathic affection, is almost unknown. It usually occurs as an accompaniment of some other disease—as syphilis, Bright's disease, intracranial disease, pregnancy, cardiac disease, etc.; but as these diseases are specially considered as sources of blindness further on, we are reduced to very narrow limits. It must be admitted that cases of neuro-retinitis are occasionally seen without apparent cause. And it is probable that such vague causes as prolonged exposure of the eyes to very bright light, with great heat, as the glare of a furnace, or to the reflection of the sun from the waters of the tropics, or from excessive use of the eyes by strong, artificial light, may produce the disease and thus lead to blindness.

(11) *Detachment of the Retina and* (6) *Choroiditis Myopica.*—Myopia, the cause common to each of these conditions, is of great importance, and merits careful consideration. It may be said to be an outgrowth of civilization and education, and it may be taken as an index of the studious habits and of the close eyework of a people. In this present busy age of progress and competition, which calls for work at high pressure, and necessitates the forcing process as soon as school days are begun, there are many causes at work which serve to swell the ranks of myopes, and to lay the foundation for its future increase. The long hours of confinement in the schoolroom, and the lack of proper out-of-door exercise and fresh air, tend to cultivate sedentary habits and to lessen the resisting power of the tissues of the body. The close application of the eyes at near work, with badly constructed desks and insufficient illumination, which necessitate stooping over the pages and straining the eyes, brings on congestion of the fundus of the eye, with thinning and bulging of the sclera at the point of least resistance—the posterior pole; and the development of myopia is the consequence. This condition, once produced, is increased by a continuation of the causes which induced it; and, in unpromising subjects, even the removal of these causes does not put a stop to its progress.

The development and increase of myopia during school life are nowhere better shown than in the following table, taken from Fuchs and prepared by Cohn. The village school corresponds to our lowest grade, and then follow in regular sequence the higher grades, until the last or university course is reached:

TABLE XI.

	Percentage of myopia.	Degree of myopia.
Village school	1.4	$\frac{1}{24{\cdot}4}$
Elementary school	6.7	$\frac{1}{22{\cdot}7}$
Intermediate school	10.3	$\frac{1}{21{\cdot}9}$
High school	19.7	$\frac{1}{19{\cdot}6}$
Gymnasium (college).	26.2	$\frac{1}{18{\cdot}7}$
University	59.0	$\frac{1}{12{\cdot}2}$

It was furthermore noted that the percentage of myopia increased in each school from class to class. Among theological and medical students, whose term of study is prolonged beyond the ordinary university course, the percentage of myopia is still further increased, reach ing in the case of theological students seventy-eight per cent. And in reference to confinement and indoor life on the one hand, and out-of-door life and exercise on the other, Erisman found the percentage of myopia in resident scholars to be forty-two per cent., and in day scholars to be thirty-five per cent. Dor found even a greater difference—thirty-three per cent. against eighteen per cent.

Myopia abounds among studious people, and is almost unknown among the ignorant and illiterate. It is not congenital, yet the tendency to its development is certainly transmitted from parent to child. The prophylactic measures against myopia are of the utmost importance. First and foremost are: A proper amount of out-of-door exercise during school life; well-ventilated schoolrooms, with good illumination, properly constructed desks, so that the light will fall to best advantage upon the page, and avoidance of the habits of stooping or bending the head over the work, and of holding objects close to the eyes. After the development of myopia, much can be done for its relief by the use of atropine and the wearing of properly selected glasses. It should be remembered that myopia fosters sedentary and studious habits; and it at times becomes advisable to discontinue the use of the eyes for near work altogether; and it not infrequently falls within the province of the physician to decide upon the child's future mode of life and employment.

A few cases of myopia with choroiditis occur independently of the causes here ascribed to it; yet they are so infrequent that they may be left out of consideration. And, too, detachment of the retina is sometimes seen in eyes that are not myopic; but it rarely occurs in such as a primary affection, and when secondary to some other pathological lesion, that, and not the detachment, is the cause of blindness.

(12) *Glaucoma.*—The importance of this disease, as indicated by its quota of blind, is forcibly increased, when its usual amenability to treatment is considered. While a well-marked case of glaucoma presents unmistakable symptoms of the disease, which it would be unpardonable to overlook, there are other cases which are obscure and misleading. The very fact of this uncertainty should, however, put us upon our guard; and there are few cases indeed which would run the gauntlet of careful examination and close observation. Once recognized, prompt and energetic treatment is indicated; and there is no operation in the whole range of surgery that affords more brilliant results than does iridectomy in cases of acute glaucoma. Sclerotomy and eserine have their spheres of usefulness; and stretching the external nasal nerve has recently been much lauded in the treatment of certain obstinate forms of glaucoma. Unfortunately the more obscure cases attract but little attention until the disease is far advanced, and medical advice is sought only after serious and permanent impairment of sight comes on. A more thorough knowledge of the disease and greater familiarity with its symptoms by the general practitioner will not only insure its more prompt recognition, but will lead the laity to a better understanding of the affection, and cause greater care in the observance of eye symptoms. A few cases of glaucoma are strongly allied to optic-nerve atrophy, and these are very unfavorable.

(13) *Idiopathic optic-nerve atrophy* occurs most frequently in subjects who have inherited a tendency to nervous disorders. It is often a precursor of spinal cord or of cerebral disease; and as the length of time which may intervene between the development of optic atrophy and central changes is often considerable, the diagnosis is usually difficult and uncertain. The disease is one of the most obscure that we have to deal with, and the prognosis is unfavorable. It is much more frequent in men than in women.

(14) *Tumors of the Eye and its Surroundings.—Malignant diseases*, as glioma of the retina, sarcoma of the choroid, of the ciliary body, and of the iris, and epithelioma or lupus of the conjunctiva, or of the cornea, may produce blindness through destruction of the globe by their own growth; yet their chief importance is in their danger to life. Cysts of the iris, if they are not removed, may cause blindness by increase in size.

Gummata of the ciliary body and of the sclera may also produce blindness in the same way. Other tumors of the eye rarely cause blindness. Tumors arising from parts adjacent to the eye may produce blindness, directly by extension of the disease to the globe, or indirectly by pressure effects upon the globe or optic nerve, as is seen in vascular and cystic tumors of the orbit, and in tumor or distention of the frontal, ethmoidal, nasal, or maxillary sinuses.

(15) *Unclassifiable.*—The percentage here given may be taken as a fair example of the proportion of the blind which present such complicated conditions as to preclude classification.

(16) *Direct Injury of the Eyes.*—The more important proportion of these cases occur in individuals whose labor necessitates exposure of the eyes to flying bits of metal or stone, as machinists, workers in stone, miners, etc., and in those who have to deal with explosives, as in blasting, the manufacture of explosive materials, etc. The use of protective glasses, preferably of mica, which combines perfect transparency with considerable strength, is a measure that would afford much protection to the eyes, though it has been but little adopted by workmen exposed to these dangers.

A certain number of cases occur from unavoidable and unforeseen accidents, and of these it is unnecessary to treat.

Injuries of the eye in the German army during the Franco-German war (1870–71) were met with in 786 cases —being 0.79 per cent. of the whole number of injuries, and 7.8 per cent. of head injuries; and affections of vision after head injuries were met with in 74 cases—or 0.7 per cent. of head injuries.

(17) *Unsuccessful Operations.*—The percentage here furnished certainly appears small, when it is considered that many eye operations are attended with considerable risk to the eye, even in the hands of the most accomplished operators. Cataract extraction—the most important operation in ocular surgery, and at the same time the most formidable—is accountable for most cases of blindness from operative measures. As it is performed late in life, when the process of repair is impaired by age and often by disease, it is to be wondered that the proportion of unfavorable results is not larger.

(18) *Injuries of the head* produce blindness through lesions of the optic nerve, at or about the optic foramen. It is known that blows upon the head may cause fracture of the bones about the apex of the orbit, or at the optic foramen; and blindness ensues from injury to the optic nerve—immediately if the injury be severe, and more slowly if dependent upon secondary degenerative changes (atrophy). Meningitis following injuries of the head may cause optic neuritis or atrophy and blindness. And injuries of the angular gyrus may produce blindness.

(19) *Traumatic Sympathetic Ophthalmia.*—This is one of the most important of eye diseases, and, because of its insidious character and its intractable and uncertain course, merits the utmost care in its consideration at the hands of ophthalmologists, and general practitioners as well. Resulting, as it does, from previous mechanical injury which has greatly impaired or entirely destroyed the fellow eye, its treatment involves great responsibility. And as it not infrequently happens that the sympathizing eye is ultimately left in a worse condition than the exciting one, advice should be well and intelligently considered. The disease may appear within a few weeks, or it may not develop for years; and while its prodromes may extend over periods varying from weeks to months, it sometimes comes on unannounced, and quickly leads to blindness. Arising at times from wounds, apparently trivial, in the ciliary region, it occasionally fails to appear after extensive injury to this, the vulnerable zone. Treatment of the disease after it has developed is of course important, and while it is sometimes unsatisfactory, it is

usually productive of great good. The measure above all others to be adopted is prophylaxis; and this includes the proper care of the primarily injured eye, as well at the time of the injury as later on; and this of course involves the question of enucleation. This is an important problem, and there are many points to be carefully considered before a conclusion is reached. It may be stated as a cardinal point, however, that an eye so seriously injured in the ciliary region as to preclude the possibility of retention of sight should be promptly removed; for such an eye is not only a useless organ, but is a source of constant menace to its fellow.

(20) *Diseases of the Eye from Syphilis.*—Syphilis is a prolific source of eye disease, and may cause almost any form of it. The *inherited* form of syphilis, through defective development or inflammation of the several parts of the eye during intra-uterine life, may cause blindness. And abnormalities in the osseous development of the orbit or of the skull may, through pressure upon the visual tract, cause optic neuritis or atrophy and blindness. Diffuse (parenchymatous) keratitis—a disease of early life—is also occasionally productive of blindness. Either the *inherited* or the *acquired* form of syphilis may cause blindness through kerato-iritis, iritis, irido-cyclitis, irido-choroiditis, choroiditis, retino-choroiditis, and optic neuritis or atrophy. In tertiary syphilis, gummata—affecting by preference the sclera or the ciliary body—may produce destruction of the eye. And the periosteal or bony lesions of this stage may cause, through participation or by their pressure effects, disease of the eye or of its conducting apparatus, which leads to blindness. An early recognition of the specific taint, and prompt and energetic measures against it, constitute the sheet-anchor of success in all diseases dependent thereon.

(21) *Gonorrhœal Conjunctivitis.*—This is a most virulent form of purulent ophthalmia, due to inoculation of the conjunctiva with the discharge from a specific urethritis or vaginitis. The material is conveyed to the eye by accident or by carelessness, through unwashed hands in persons with gonorrhœa, or in those treating it, and the use of towels or of linen which have become contaminated. Perfect cleanliness and care, observed by gonorrhœal subjects and by their attendants and associates, would expel this disease from the category of eye affections.

(22) *Scrofulous Diseases of the Eye.*—The strumous condition is a fruitful source of eye disease, yet the diseases to which it most frequently gives rise—ophthalmia tarsi, phlyctenular troubles, etc.—seldom cause blindness. One of its diseases, however—cyclo-keratitis—is a most serious disease, and often produces blindness. It was first described by Dalrymple, and is sometimes spoken of as Dalrymple's disease. It is fortunately rare. Lupus is usually considered a strumous disease, and this may lead to destruction of the eye—whether attacking the eye primarily, or involving it secondarily. Tuberculosis may also cause blindness, through choroiditis, iritis, and keratitis.

(23) *Irido-choroiditis with Meningitis.*—This disease is commonly spoken of as metastatic choroiditis, and is caused by an extension of inflammation from the head to the eye in simple meningitis, or, as is more frequently seen in cerebro-spinal meningitis, by metastasis. The disease usually destroys the eye, and treatment is ordinarily unavailing.

(24 and 25) *Atrophy of the Optic Nerve* (*Cerebral and Spinal*).—It is often difficult and sometimes impossible to locate the lesion upon which optic-nerve atrophy depends, and it will be convenient to consider these two forms together. According to Galezowski, who tabulated 166 cases of optic-nerve atrophy, about 50 per cent. are due to diseases of the brain and spinal cord; 13 per cent. are traumatic; 9 per cent. are due to alcoholism; 8 per cent. to syphilis, and the remaining causes are of the most varied kind. And according to von Graefe, about 30 per cent. of cases of primary atrophy of the optic nerve are due to spinal disease.

Cerebral optic-nerve atrophy may be consecutive to optic neuritis (of central origin), or it may follow lesion of the chiasm, of the cerebral centres, or of the cortex about the angular gyrus, or it may be caused through pressure upon the nerve by an exostosis, tumor, or aneurism; through narrowing of the optic foramen by hyperostosis or by pressure upon the chiasm from distention of the third ventricle. Meningitis, chronic or acute, may also cause ptosis, or atrophy without recognized neuritis, etc. *Spinal atrophy* occurs with locomotor ataxia, of which it may be the earliest symptom; or it may, as is often the case, come as a late manifestation of the disease.

(26) *Atrophy of the Optic Nerve, or Neuritis after Hæmatemesis.*—Loss of blood is occasionally followed by affection of vision, which may be temporary or permanent. It is with the latter that we have to deal, and this usually depends upon either neuritis or atrophy. Clinical experience has taught that hemorrhages from the gastro-intestinal tract cause disturbance of vision more frequently than hemorrhages from other localities (thirty-five per cent.). The connection between the loss of blood and disease of the optic nerve has so far received no satisfactory solution. The same connection probably exists between *atrophy of the optic nerve after bleeding from piles* (27), and *after dysentery* (28).

(29) *Atrophy of the optic nerve after vomiting* is rare, and the connection between the two is obscure. The straining and consequent congestion may produce retro-ocular hemorrhage, or serous effusion; or it may be due to the connection which exists between the stomach and the corpora quadrigemina.

(30) *Optic-nerve atrophy after facial erysipelas* is usually caused by an extension of the cellulitis to the tissue of the orbit, and the resulting damage to the trunk of the nerve.

(31) *Atrophy of the Optic Nerve with Insanity.*—Atrophy sometimes occurs among the insane, and most frequently in subjects of general paresis—though it sometimes occurs in dementia and in other forms of insanity. It is a degenerative change, associated with similar lesions in the central nervous system.

(32) *Atrophy with Epilepsy.*—It does not appear that idiopathic epilepsy has connection with any form of eye disease. It is only in such cases as are dependent upon gross intracranial lesions that changes are observed in the disc, and the atrophic changes here differ in no way from those seen in the usual forms of brain disease.

(33) *Retinitis nephritica* occurs in about twenty-five per cent. of cases of chronic Bright's disease. It is more important as a means of diagnosis than as a cause of blindness, for not infrequently it is the first symptom which leads to a detection of disease of the kidney. It rarely causes blindness, however, in spite of the marked pathological changes that are noticeable in the retina, and often in the optic nerve.

(34) *Diseases of the Eye with Typhoid.*—Loss of sight has been many times observed during convalescence from typhoid fever, and, subsequently, optic-nerve atrophy has usually been found. In some of these cases cerebral symptoms have been observed, and in others there was none. Keratitis is sometimes seen, and blindness may be one of its consequences.

(35) *Blindness from measles* may be due to optic neuritis, or it may result from neglected diseases of the external eye, *i.e.*, conjunctivitis, keratitis, etc.

(36) *Disease of the Eye from Scarlatina.*—The frequency with which renal disease accompanies scarlet fever renders affections of sight not very rare consequences of the disease. Yet neuro-retinitis does occur without the presence of renal disorder. Atrophy of the optic nerve may also be the result of scarlatina. In malignant cases sloughing of the cornea has been observed, and in other cases keratitis may produce blindness.

(37) *Disease of the Eye from Variola.*—Variola may cause neuro-retinitis or atrophy of the optic nerve; but its chief danger is from diseases of the external eye, almost any part of which may be the seat of the eruption. The most dangerous seat is the cornea, where ulceration often leads to blindness. Iritis has also been observed.

TABLE XII.

Preventable causes of blindness.	Per cent.	Probably preventable blindness.	Per cent.	Unpreventable blindness.	Per cent.
Ophthalmia neonatorum	10.876	Diseases of the cornea	4.034	Diseases of the cornea	4.034
Trachoma and blennorrhœa	9.492	Direct injuries of the eye	2.017	Direct injuries of the eye	2.017
Diphtheritic conjunctivitis	.356	Unsuccessful operations	1.978	Tumors of eye and surroundings	.356
Choroiditis myopica	.949	Irido-choroiditis, cyclitis, iritis	4.430	Irido-choroiditis, cyclitis, iritis	4.430
Detachment of retina	3.746	Detachment of retina	1.000	Injuries to the head	.277
Glaucoma	8.000	Glaucoma	.978	Scrofulous diseases	.039
Sympathetic ophthalmia	4.509	Unclassifiable	1.681	Unclassifiable	1.681
Gonorrhœal ophthalmia	.910	Diseases of the eye from syphilis	.238	Disease of eye from syphilis	.238
Diseases of eye from smallpox	2.216	Choroiditis, chorio-retinitis	.369	Choroiditis, chorio-retinitis	.738
Intoxication amaurosis	.039	Idiopathic optic-nerve atrophy	2.000	Idiopathic optic-nerve atrophy	5.751
		Optic-nerve atrophy, cerebral	2.000	Optic-nerve atrophy, cerebral	4.961
		Optic-nerve atrophy, spinal	.333	Optic-nerve atrophy, spinal	2.000
		Typhoid, measles, scarlatina, etc	1.165	Typhoid, measles, etc	1.165
				Irido-choroiditis with meningitis	1.424
				Other causes, including 3.835 per cent. of congenital blindness	5.412
	41.093		22.223		34.523

Important as the local treatment of these disorders may be, the prophylactic measure of vaccination should supersede them all, and thus prevent entirely the disease upon which they depend.

(38) *Disease of the Eye from Heart Trouble.*—The most frequent cause of blindness from heart disease (valvular) is the so-called embolism of the central artery of the retina. This is usually monocular, but sometimes both eyes are affected. Thrombosis of the central vein of the retina behind the eye, in association with disease of the heart, may also produce blindness. In ulcerative endocarditis retinal hemorrhages often occur, and sometimes panophthalmitis is observed.

(39) *Diseases of the Eye from Childbirth or Pregnancy.*—In pregnancy we are liable to have albuminuric retinitis, and, following childbirth, we may have metastatic choroiditis, or retinal hemorrhage; and cases of atrophy of the optic nerve are sometimes dependent upon lactation.

(40) *Intoxication Amaurosis.*—Under this head are included cases of blindness resulting from the abuse of certain noxious agents, chief among which are alcohol and tobacco. It is claimed that the free and long-continued use of either of these substances not infrequently leads to a form of optic-nerve atrophy possessed of certain distinctive peculiarities. There seems to be good reason for attributing such to alcohol, but the reasons in favor of tobacco are not so strong.

(41) *Blindness from Diseases of the Orbit.*—Inflammatory processes in the orbit, whether in the cellular tissue or in the periosteum or bone, may cause either simple atrophy of the optic nerve or neuritis and consecutive atrophy. With much swelling of the orbital tissue there is danger that the nutritive supply of the globe may be cut off by pressure, and that the inflammation or sloughing which results may produce blindness. Tumors of the orbit may act as inflammatory products, or, the disease extending to the eye, may directly cause destruction of this organ.

An important matter in the consideration of the causes of blindness, is the proportion composed of those whose origin is unavoidable, and the course of which is beyond control. If arranged under the headings of *Preventable*, *Probably Preventable*, and *Unpreventable Blindness*, we are at once struck with the large number included under the *first* and *second* headings, and the small proportion embraced under the *last*. Absolute accuracy in this arrangement is, of course, not claimed, but it will serve the purpose of illustrating the large amount of blindness arising from avoidable causes, and such as are amenable to treatment.

It may be of interest to state that the first institution for the blind was founded in Memingen, by Weef VI., in 1178; the second in Paris, by St. Louis, in 1260; the first for the employment of adult blind was opened in Edinburgh, by Dr. Johnston, in 1793. There were, in 1873, one hundred and forty-eight institutions for the blind in the world.

There are certain *irregular forms of blindness* which will be treated of under appropriate headings elsewhere, and it will be necessary to refer to them here only in a general way. The free exhibition of *quinine* or of *salicylic acid* sometimes causes blindness, and it has been observed in rare instances to follow the use of *silver*, of *mercury*, and of *lead*. Prolonged exposure to the fumes of *sulphide of carbon* may produce amblyopia; and the fumes of *osmic acid* may bring about the same condition. The circulation, in the blood, of a superabundance of *urea* is apt to cause transient attacks of blindness. And in *migraine*, or sick headache, attacks of blindness are not infrequent. The attacks of blindness in the foregoing conditions of the system are usually transient, and perfect recovery quickly follows: yet, if they are often repeated, permanent impairment of sight may result, which in some instances declares itself as a low grade of optic neuritis or atrophy. *Hysterical amblyopia* is a recognized condition. It is temporary and irregular, and is usually attended by other hysterical symptoms. Temporary blindness may occur as the *aura* of an *epileptic attack*. Cases of *word-blindness* which were dependent upon lesions about the angular gyrus have been observed in individuals who could talk and even write. *Night-blindness* or *moon-blindness*—hemeralopia—is a condition of torpor of the retina which usually affects those who have been long exposed to bright lights—as sailors or marching soldiers, in the tropics. Insufficient food, either as to quantity or quality, seems also to be a factor in the disease. *Day-blindness*, or *nyctalopia*, is a form of retinal hyperæsthesia which is also usually caused by long exposure to glistening surfaces brilliantly illuminated by the sun. *Snow* or *ice blindness* is a variety of nyctalopia, though there are usually with this form signs of conjunctival implication. *One-sided blindness*, or *hemianopsia*, which may exist in various forms, is occasionally seen, and it is often of importance in locating intracranial lesions. *Blindness from disuse—amblyopia ex anopsia*—is claimed by many to result from the long-continued disuse of an eye. *Simulated blindness* can usually be detected, yet it is often done with difficulty. *Color-blindness — achromatopsia* — may exist in various forms. It is of great importance, and receives ample consideration elsewhere.

Prevention of Blindness.—Much can be done toward peventing blindness through a better understanding of its causes by the laity, while the profession should not only be alive to these points, but should be able quickly to recognize diseases of the eye, and acquainted certainly with the simpler forms of treatment. The most prolific source of blindness—ophthalmia neonatorum—can be stamped out by the observance of the simplest procedure—Credé's method—already referred to. So important is this disease that the legislatures of some of the European countries, and of some States in our Union, have enacted laws for the guidance of those concerned.

The act of New York, which will serve as an illustration, is given here:—

"An Act to Prevent Blindness.

"Sect. 1. Should any midwife or nurse having charge of an infant in this state notice that one or both eyes of such infant are inflamed or reddened at any time within two weeks after its birth, it shall be the duty of such midwife or nurse, so having charge of such infant, to report the fact in writing within six hours to the health officer, or some legally qualified practitioner of medicine, of the city, town, or district in which the parents of the infant reside.

"Sect. 2. Any failure to comply with the provisions of this act shall be punishable by a fine not to exceed one hundred dollars, or imprisonment not to exceed six months, or both.

"Sect. 3. This act shall take effect on the first of September, 1890." *James Lancelot Minor.*

BLISTERS.—This subdivision of agents, otherwise and technically known as vesicants or epispastics, belongs to the larger order of so-called Irritants. They also belong, in the arbitrary classification of drugs, to the Neurotics—on account of their counter-irritant action, which effect is produced largely through the nervous system. There are four degrees of irritant action, and these are expressed in the following classification: (1) Rubefacients; (2) Vesicants or Epispastics (blisters); (3) Pustulants or Suppurants; and (4) Escharotics. Each of these, which differ only in degree, represents substances, which, when applied to the skin, produce more or less irritation, *i.e.*, vascular reaction or excitement. Rubefacients, by rousing the capillaries, are intended to excite mere redness; if allowed to remain in contact with the skin too long, they sometimes produce vesication. Epispastics applied to the skin excite not only redness but also more or less local inflammation, accompanied by the transudation of serum beneath the cuticle. Such fluid transudations, forming between the epidermis and the dermis, at first minute, soon coalesce into one or more larger accumulations, called a *blister*.

The list of principal vesicants includes cantharides, iodine, the volatile oil of mustard, the confined vapor of ammonia, the confined vapor of chloroform, chloral hydrate crystals (if confined), glacial acetic acid, rhus toxicodendron, euphorbium, mezereon, heat in the form of Corrigan's hammer, the moxa or plain boiling water, also turpentine and other agents. All of these may act either as mere rubefacients or as vesicants, according to the length of time during which they are permitted to remain in contact with the surface of the skin, and also according to their degree of concentration.

Physiological Action.—When a blister is applied to the integument, the superficial vessels, and particularly the capillaries, become engorged; and at the same time the subject of the experiment feels a sense of warmth and tingling, which latter soon gives way to heat, burning, and actual pain. Reflexly, the deep-seated vessels may also undergo dilatation, and in this consists the *counter-irritant action* of blisters. After a variable length of time—dependent upon the character and activity of the vesicant employed, as well as, also, to some extent, upon the histological character of the tissue to which the blistering agent is applied—clear serum, plasma, and finally, in some instances, more or less blood corpuscles escape from the vessels and collect between the epidermis, which is now raised, and the true skin, forming what is known as a bleb, blister, bulla, bulle (French), Blase (German). Occasionally, where the blistering material is weak, its action may cease with mere capillary dilatation, heat and redness (rubefacient effect). On the other hand, it is possible, for a very strong and active epispastic, if kept for too long a time in contact with the skin, to act with such force, as to cause pustulation. The size of the vesicle is proportionate to the dimensions of the blistering material used, the surrounding skin being more or less inflamed and erysipelatous in appearance. Primarily, a stimulant action is observed not only in the organs and parts in close proximity to the blister, but also in the entire superficial circulation. With this is associated a corresponding diminution in the deep-seated vascular pressure, and this secondary depression is proportionate to the size of the blister or, more properly, to the amount of albumin abstracted from the blood. Under certain circumstances, and especially in old or debilitated persons, this depression may become alarming.

The exact *modus operandi* of vesicants is not clearly understood. By some the counter-irritant action is thought to play the most important part, and these persons explain this action as taking place through the nervous system. They maintain, that, by a determination of nervous as well as vascular energy to the blistered part, there is produced a derivative or revellent effect in the deeper structures,—an effect, which is accompanied not simply by anæmia, but also by changes in the nutrition and secretion of the organ or part affected. Other authorities attach importance to the stimulant action, which is exerted, by extension, upon the capillaries of the inflamed structure or structures (in behalf of which the blister was applied to the skin).

Uses of Blisters.—To relieve pain; to reduce swelling and to allay deep-seated inflammation; to facilitate absorption; to stimulate secretion; to recall suppressed discharges or to recall suppressed inflammation, as in mumps (see below); to stimulate the whole body, as in syncope (or in coma), or a part of the body, as in paralysis; to prepare a surface for endermic medication. Blisters are employed to good advantage in chronic inflammation of joints, either of rheumatic or of gonorrhœal origin; in chronic thickening about the joints; in chronic synovitis and periostitis; in spinal and in cerebral meningitis; in insolation (sunstroke); in optic neuritis and in iritis (applied behind the ears); in otitis media; in mastoid inflammation and in inflammation of the sinuses (frontal sinus, antrum of Highmore, etc.); in neuralgia, gastralgia, enteralgia; in pleurodynia; in hysterical paralysis; in facial paralysis; in reflex cough; in aphonia; in obstinate vomiting; in enuresis; in spermatorrhœa; in alcoholic or opium narcosis; in lumbago; in sciatica; in endocarditis, pericarditis, and pleuritis; in hydropericardium or in dropsy of other sacs, especially in hydrocephalus; in hepatitis, splenitis, ovaritis; in metastatic orchitis (of mumps, when it is well to place the blister over the parotid); in prostatitis and in chronic gleet. Blisters are also employed to stimulate indolent ulcers or fissures; and in chronic eczema and other chronic dry and scaly skin disorders, especially of a somewhat inflammatory character, to substitute a healthy, acute inflammatory action for the existing, long-continued, chronic inflammation. What the action of blisters is in such cases is not known, but they have been used to good advantage in erysipelas, as a means of preventing the spread of the process. In functional diseases of the nervous system, the counter-irritant action and the stimulant as well as the moral effect of the blister almost invariably prove salutary. Good results have also been reported from the application of a blister over the perineum in spermatorrhœa, over the back of the neck in incontinence of urine, and over the epigastrium in persistent nausea.

Contraindications.—Blisters should be avoided in the very young, in the very old, and in those who are debilitated, or who have depressed vital forces. They should never be applied in the following situations: directly over an inflamed part, over a bony prominence, over a part pressed upon by clothes, over recumbent parts which are pressed upon in bed, over parts which are deprived of vitality by the presence of cicatricial tissue or by paralysis—in a word, over any part in which the circulation is poor, and in which consequently the blister might cause gangrene and sloughing. In parts of the body, where there is considerable loose connective tissue—such, for example, as the scrotum, the labia, the eyelids, or the axilla—blisters should not be applied. In pregnancy, also, it is best not to make a blistering application about the breasts. Diabetes, scurvy, purpura, and the acute exanthemata contraindicate the use of blisters. Too long contact of the vesicating material with the skin should be carefully avoided, as deep ulceration may occur, and a special warning must be given in regard to cantharides, which should not be allowed to remain too long over any portion of the thorax or abdomen, lest inflammation of the pleura or of the peritoneum arise. Cantharides should blister in from four to seven hours. The confined vapor of aqua ammoniæ fortior acts in from three to ten minutes, but a blister thus produced is very painful. For this reason, the following mixture, called Granville's lotion, is preferable: it consists of five parts of the aqua ammoniæ fortior, two parts of the spirit of camphor, and one part of the spirit of rosemary. A piece of flannel is saturated with this lotion and laid on the skin. It will produce a blister in from three to ten minutes. Gondret's vesicating ointment is also very satisfactory. It is prepared with two parts of expressed oil of almond, melted together with thirty-two parts of lard, and to which seventeen parts of aqua ammoniæ fortior are added. It will blister in ten minutes, causing less pain than plain ammonia does. Pain is not always a safe guide, as regards the time when the blistering agent should be removed, and this is especially true in cases in which blisters are applied as stimulants—as, for example, in syncope or in the shock following hemorrhage or injury,—for, in these conditions, pain may be entirely wanting. Cantharides, the prince of blistering agents, is contraindicated, as a rule, in renal disease, also in inflammatory conditions of the genito-urinary tract, in which it is accused of producing priapism, erotic excitement, strangury, pain, tenesmus, bloody urine, and the like. These latter very distressing effects of cantharides may be prevented, at times, by the use of powdered camphor or bicarbonate of soda, sprinkled on the blistered surface. A thin piece of silver paper, spread over the blister, is also said to prevent strangury.

Synergists.—On the absorbents, the action of blisters is aided by alteratives; and it is also probable that the various drugs, that belong to the class of stimulants synergize vesicants. The blister either may be permitted to heal or it may be converted into a running sore, just as the physician may prefer. Perpetual blisters, however, are very seldom employed to-day. In fact, the hitherto very commendable custom of blistering has fallen into an undeserved disrepute in recent years. So soon as the blister has formed, it is well to puncture it at its most dependent point, allowing the serum to escape. Then a simple dressing of cerate or any other bland, unirritating material will favor prompt healing. Basilicon salve or other more irritant ointment may be employed in those cases in which it is intended to maintain the discharge. When the vesicant has been removed, and no blister forms, a bread-crumb poultice, made with milk, will help it to develop. Lead water and laudanum is recommended as an application for painful blisters. A succession of small blisters, applied one after the other, whereby continuous counter-irritant action is obtained, represents what are termed "Flying Blisters." Besides the commonly employed Spanish fly plaster, which is made by mixing ceratum cantharidatum with wax and spreading it on a thin cloth, there are numerous other cantharidal preparations—ethereal, alcoholic, watery, and hydrochloric extracts of cantharides,—all more or less active; and, among these, none is more useful than cantharidal collodion. It possesses one great advantage: it can be applied to any surface, no matter how irregular it may be. As an application in alopecia circumscripta (functional) and in tinea tonsurans and circinata, collodium cantharidatum is much used. The cantharis vittata or potato fly, inhabiting the potato plant of the United States, contains a percentage of cantharidin, and resembles, in its effect, the imported Spanish fly.

It is to be hoped that the pendulum will one day, in the near future, swing back from its present extreme position, and give to this branch of our therapeutic armamentarium its proper place. The statement has been made by the former writer upon this subject in a previous edition, that venesection, only, can so quickly and radically induce changes in the physical and physiological condition of limited areas of surface or of extensive parts or organs as vesication. If this statement be true, and we believe that it is, then it were well for steps to be undertaken to instruct the profession in a therapeutic procedure which is fast disappearing.

Leon L. Solomon.

BLOCK ISLAND.—This island (Lat. 41° 13′ N., Long. 71° 35′ W.), lying some ten miles out at sea, and situated about midway between Point Judith, on the Rhode Island coast, and Montauk Point, the eastern extremity of Long Island, is, with perhaps the single exception of Nantucket, farther distant from the mainland, and consequently more thoroughly exposed to purely maritime influences, than is any other resort lying along the Atlantic coast of the United States. According to "Lippincott's Gazetteer," the length of the island, from north to south, is eight miles; its breadth from east to west varies between two and five miles. The greater part of the island is considerably elevated above sea level. The rocky bluffs lying upon its southern and southeastern shores are said to rise some two hundred feet above the water, rendering this part of its coast exceedingly picturesque and bold in appearance; while an elevation of some three hundred feet is said to be attained in some parts of the interior. The general surface of the island by no means consists, however, of a uniformly elevated tableland, but is decidedly undulating and of uneven configuration. On the eastern shore, where the chief hotels are located, there is a fine beach for bathing. The facilities for boating and for fishing are also said to be unsurpassed. Besides the meagre account of Block Island contained in the pages of "Lippincott's Gazetteer," the writer has hitherto seen no description of the island, save that contained in the two pamphlets circulated as advertisements of its hotels. In these pamphlets, however, there is to be found a long extract from an account of Block Island as a health resort, written by Dr. H. Holbrook Curtis, of New York, a physician who was formerly in the habit of passing his summers at this seaside resort. The reputation of this gentleman is such as to give the greatest weight to his comments, which are based, moreover, upon personal experience. In this article, published originally in the pages of the New York *Medical Record*, Dr. Curtis bears witness to the exceptional purity of atmosphere existing at Block Island, to the coolness of the place in summer, to the bracing and remarkably tonic, as well as soothing, effect of its climate, and to the decided benefits attainable and attained by a summer sojourn at this spot in cases of nervous prostration, insomnia, malarial poisoning, and in some cases of pulmonary phthisis. The doctor also testifies to the good quality of the water supply, the comfort of the hotels, and the perfect system of drainage in vogue at the latter. His article also contains a table, showing the temperature at noon for each day of the two months of July and August, 1880, as taken by a gentleman who was staying at the island. Similar tables for those two months during the years 1881, 1882, and 1883, based also upon private observations, are given elsewhere in the two pamphlets already referred to. From the figures of these four tables the present writer has deduced by calculation the following chart, which shows the average noon temperature for July and August, in each of the four years specified (1880, 1881, 1882, and 1883), as also the absolute maximum and absolute minimum noon temperatures, the average maximum and minimum at noon, the absolute and the average range, and also the absolute and the average number of days in each month upon which the mercury rose to 80° F. or above, and upon which it stood at 70° F. or lower, at the hour specified. A glance at this table will show not only the coolness, but also the great evenness of the midday temperature at this exceptionally and truly maritime resort.

Noon Temperatures at Block Island. (Fahrenheit Scale.)
(July and August, 1880, 1881, 1882, and 1883.)

		Average.	Maximum.	Minimum.	Monthly range.	Number of days on which temperature was at or above 80° F.	Number of days on which temperature was at or below 70° F.
1880	July ..	75.5°	81.0°	70.0°	11.0	3.0	4.0
	Aug ..	74.3	82.0	62.0	20.0	3.0	5.0
1881	July ..	73.4	80.0	66.0	14.0	2.0	9.0
	Aug ..	72.2	79.0	58.0	21.0	0.0	9.0
1882	July ..	74.2	82.0	60.0	22.0	6.0	6.0
	Aug ..	74.4	80.0	68.0	12.0	1.0	6.0
1883	July ..	73.8	80.0	65.0	15.0	2.0	6.0
	Aug ..	72.6	80.0	66.0	14.0	2.0	9.0
Average	July ..	74.22	80.75	65.22	15.5	3.2	6.2
	Aug ..	72.37	80.22	63.50	16.7	1.5	7.2

Huntington Richards.

[Below are added some more recent data in regard to the climatological conditions which exist at Block Island:

Meteorological Data of Block Island for the Four Months, June, July, August, September, from 1890 to 1897 Inclusive, from the United States Weather Bureau. (Fahrenheit Scale.)

	Mean average temperature for the four months.	Mean maximum temperature.	Mean minimum temperature.	Relative humidity.
1890	65.2°	73.0°	60.0°	87.3°
1891	65.2	81.0	52.7	89.0
1892	65.7	81.0	53.0	86.4
1893	64.4	79.7	51.5	85.0
1894	65.9	80.5	52.5	85.5
1895	65.8	81.5	50.0	86.6
1896	65.5	80.0	52.5	86.5
1897	65.4	79.9	51.7	85.7

The temperature of the summer proper is 67° F.; of autumn, 53° F.; winter, 32° F.; spring, 43° F.; and the annual mean, 56° F. The mean annual rainfall is 53 inches. Sunshine for summer, 63 per cent.; autumn, 43 per cent.; winter, 51 per cent.; and spring, 48 per cent. Annual mean, 53 per cent. (*Medical Record*, 1897).

The island is reached from New York, Providence, Newport, and New London. From the private letter of a gentleman who has passed many summers on the island, the following is extracted:

"There are more or less fogs on the island, but generally not enough to be uncomfortable; the bathing is good and perfectly safe. There is almost always a breeze, and of course no land breeze, so that the weather is cool and comfortable, and no one need fear any discomfort from the heat; there is practically absolute freedom from mosquitoes."

In another private letter of a gentleman who spent two months on the island it is stated that "the bathing is poor, dangerous on the seaward side, and stormy on the protected side." As he was unfortunate in meeting with an unfavorable season—"damp, foggy weather"—and was a sufferer from rheumatism, he may have been prejudiced in his opinion of the island and of its bathing facilities.

"There are probably twenty or thirty hotels on the island," says the former correspondent, "good, bad, and indifferent." There are also said to be cottages especially adapted for invalids and convalescents.

Block Island is a favorite place for excursionists, a condition which may be of annoyance to the summer resident.—*E. O. O.*]

BLODGETT'S SPRINGS.—Santa Clara County, California. Hotels and cottages. These excellent springs are picturesquely located in the coast range of mountains, about eight miles west of Gilroy. They are reached by the Southern Pacific Railroad to Gilroy, and from thence by a daily stage. The surroundings are beautiful. The atmosphere is pure, balmy, and invigorating, and the mineral water and baths are of considerable therapeutic value. One of the principal fountains is the Soda Spring. Anderson's analysis:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	8.20
Sodium carbonate	9.92
Sodium sulphate	Trace.
Potassium chloride	Trace.
Potassium iodide	Trace.
Potassium carbonate	0.47
Magnesium carbonate	6.65
Magnesium sulphate	1.15
Calcium carbonate	7.31
Calcium sulphate	2.19
Ferrous carbonate	Trace.
Alumina	4.13
Borates	Trace.
Silica	4.11
Organic matter	Trace.
Total solids	44.13

Gases.	Cubic inches.
Carbonic acid	9.25
Sulphureted hydrogen	Trace.

The waters are antacid, diuretic, aperient, and tonic, and of value in acid dyspepsia and catarrh of the stomach, in constipation, and in kidney and bladder troubles.

The next spring in importance is the Sulphur Spring. It is very similar in chemical composition to the Soda Spring, but contains a much larger volume of sulphureted hydrogen (7.25 cubic inches per United States gallon). This water is also antacid, laxative, tonic, and diuretic, and is said to be useful in rheumatism and sciatica, chronic arthritis, and skin diseases. Excellent bathing facilities have been constructed. *James K. Crook.*

BLOOD, CIRCULATION OF THE. See *Circulation of the Blood.*

BLOOD, FORMATION OF THE.—A complete account of the formation of the blood ought naturally to contain a discussion of the origin and maintenance of the *liquor sanguinis* or plasma, in addition to a description of the formation, growth, and life history of the different corpuscular elements which are found suspended in that fluid and which constitute, together with it, the blood. But such an inclusive use of the term would open up to discussion under this heading all the phenomena of nutrition, metabolism, and excretion, for all these are concerned in the preservation of a normal blood plasma, and would lead to a repetition of much that has been treated of elsewhere. Accordingly, we shall confine ourselves in the present article to a description of the formation of the blood corpuscles, only incidentally mentioning the first origin of the *liquor sanguinis* in the fœtus, and omitting all description of its subsequent maintenance in normal condition. It will be convenient, in treating of the origin of the corpuscles, to divide the subject into two headings and describe separately their formation during intra-uterine and during extra-uterine life, since their mode of origin is somewhat different in the two conditions; and it will also add clearness to describe in each of these two sections the formation of the red corpuscles, or erythrocytes, including here what is known concerning the origin of the blood platelets, and then separately take up the account of the white corpuscles or leucocytes.

The literature which has accumulated upon the subject of the origin, growth, and regeneration of the blood corpuscles is enormous, so that a mere recapitulation of the titles of papers written upon the subject would probably occupy more space than this entire article, which can accordingly not aim at completeness, but instead at giving a comprehensive bird's-eye view of the subject, and an outline only of the more important opinions held by various authors. At the end of the article are given a few references to *summarized* accounts of the subject from various standpoints in which some hundreds of references to other original papers will be found, and the writer here acknowledges his indebtedness to the authors of these articles for the subject matter of the present sketch of the subject.

Intra-uterine Formation of Blood Corpuscles.—It is exceedingly interesting, from the evolutionist's point of view, to note that the first erythrocytes observed in the earlier embryonic stages in man and other mammals resemble those which persist throughout life in the lower vertebrates in being nucleated cells. In the human embryo at the fourth week all the red blood corpuscles are nucleated; at the third month, the nucleated cells form only one-sixth to one-eighth of the total number of blood corpuscles; at the fifth month, the nucleated cells are still quite numerous, although present in much diminished percentage; while at birth at full term nucleated red blood corpuscles are entirely absent, having been completely replaced in the circulating blood by the biconcave discs which characterize the blood of the mammalian adult.

It is generally agreed that the earliest red blood corpuscles which have been observed, arise outside the growing embryo in a portion of the mesoblastic tissue which is known as the *area vasculosa*. Here certain pigmented patches appear, caused by the development of hæmoglobin within the cells, which are known as "blood islands," and it is generally admitted that it is in these "blood islands" of the mesoblast *outside* the growing fœtus that the first blood-vessels and erythrocytes originate. At a later stage the blood-vessels within the embryo are formed by outgrowths from these, and from similar developments taking place within the body of the embryo.

There are, however, two principal theories extant as to the manner in which the initial blood-vessels and red corpuscles are formed in the mesoblastic cells.

The earlier of these two theories, which was originally supported by Reichert and Kölliker, states that the first blood corpuscles originate from solid cords of cells which later develop to form the heart and vessels, with the contained plasma and corpuscles. These solid cords appear in the vascular area and develop so as to form a communicating network. The peripheral cells in the cord alter later to form the walls of the future blood-vessel, while the central cells become pigmented by hæmoglobin, acquire a spheroidal shape, and remain attached to the peripheral part in tufts; meanwhile a fluid appears between the masses of cells within the developing vessel which forms the future plasma; this fluid, being set in motion by the contractions of the heart which has now developed in connection with the system, detaches by degrees the adherent cells, which then circulate and form the first red blood corpuscles. The number of circulating cells is increased afterward both by indirect division of those already circulating and by increase in a similar fashion of those still adherent to the wall of the embryonic blood-vessel and their subsequent detachment. This theory has lately been somewhat revived, as a result of direct observation during life on the transparent embryos of certain fishes. Here it is said that the first fluid driven round by the developing embryonic heart is a colorless plasma, in which nucleated red blood corpuscles appear later. It is further claimed that these corpuscles can be observed becoming detached at certain areas of the vascular system, and that from the frequency of karyokinetic figures occurring in the circulating corpuscles at this stage they undoubtedly undergo increase by indirect division while circulating.

The other view, which was introduced by Klein and is supported by Balfour, Schäfer, and most English histologists, holds that the first red blood corpuscles are formed by free endogenous subdivision of the nucleus within large mesoblastic cells of the vascular area.

The cells which are to form the future blood-vessels send out processes in various directions which anastomose with one another, and later communication is established by means of these processes, so that a continuous communicating network of vessels is thus formed. Meanwhile, within each of these large branching cells alterations take place resulting in a liquefaction of a portion of the cytoplasm to form the future plasma, while the remainder continues adherent around the nucleus. Extensive proliferation of the nucleus also takes place, and around each of the daughter nuclei a portion of protoplasm forms which finally becomes pigmented with hæmoglobin, so giving rise to red blood corpuscles. Still later the intercommuicating channels enlarge so as to allow of the passage of the corpuscles along them, and by the contractions of the heart which has now developed the corpuscles are driven along the system. The primary erythrocytes formed in this way closely resemble leucocytes in their appearance and properties, possessing like these the power of amœboid movement and of increase by cell division, and differ only in the almost complete absence of granules and in the faint yellow color of their cytoplasm.

According to Howell, two distinct types of nucleated red blood corpuscles are present side by side in the blood of the early embryo. One of these types is large and oval in shape, being two to four times as long in the long diameter as the corpuscle of the adult, and being in some cases biconcave, in others biconvex. The other variety is circular in outline and of about the size of the ordinary blood disc of the adult, from which it differs in being nucleated. Howell suggests that the large oval corpuscles may represent the form of the red corpuscle characteristic of the ancestors of the mammalia, and that they may hence be spoken of as ancestral corpuscles, while the smaller circular corpuscles of the usual size of the nucleated red corpuscles of the mammalia exhibit a modification of this ancestral form which has become characteristic of the blood of most of the mammalia. These latter corpuscles afterward lose their nuclei and are converted into the biconcave blood discs, the transition taking place in the young embryo in the circulating blood stream itself, but later being confined to certain specific organs.

The first blood-vessels within the body of the embryo are probably formed in a similar fashion from cells of the mesoblast, and communicate by a network with those already developed as above described in the vascular area outside the body. Through this whole system a current of blood is driven by the contractions of the fetal heart. In the later stages of embryonic life such a general formation as has been above described of red corpuscles throughout the vascular system probably entirely ceases except in regions where new vessels are being formed. The formation of new corpuscles, to replace those broken down, or to increase the number in the circulation as the embryo grows and the vascular system increases in volume, is confined in the later stages of embryonic life to certain organs exclusively; and it is further known that the organ most active in so supplying new corpuscles varies as the development advances. At first, the liver is the most important organ in the development of embryonic red blood corpuscles, but at a later stage this organ takes up other work, and the development of corpuscles in it gradually comes to a standstill. During this period the spleen has been increasing in size, and this organ next becomes the chief seat of formation of new red blood corpuscles. Still later, as the long bones develop and become capable of taking up the function of developing erythrocytes within their marrow, the hæmatopoietic function of the spleen also becomes depressed, and soon after birth it is probable that this function of the spleen, at least under normal conditions, becomes abortive, and the red marrow of the bones is finally left the sole source of supply of erythrocytes during the remainder of the life of the animal.

That the liver becomes a seat of formation of new red blood corpuscles in the embryo almost as soon as it begins to form, was first clearly shown by Kölliker, who believed that the nucleated erythrocytes developed from certain nucleated white corpuscles contained in the developing blood-vessels, that they became pigmented from a formation of hæmoglobin, and then subsequently lost their nuclei, so becoming transformed into non-nucleated red blood corpuscles. Neumann states that the red blood corpuscles are formed within certain large cells of the embryonic liver by an endogenous division of the original nucleus and a portion of the cell protoplasm, whereby a number of nucleated corpuscles appear within the original large cell.

Howell describes the blood-forming cells in the embryonic liver as occurring, not indiscriminately, but grouped into cords or strings lying between the columns of true liver cells which are just commencing to show a definite structural arrangement. (See Fig. 509.) These cords of cells develop into the blood-vessels, and it is probable that the peripheral cells, by flattening and otherwise altering, form the endothelial wall of the vessel, while the central cells are set free as red blood corpuscles. Also at places the solid mass of cells is interrupted by vacant spaces filled with plasma which contains only a few fully developed red corpuscles either with or without nuclei. The masses of cells above described are at first colorless, but afterward they develop hæmoglobin, thus becoming pigmented.

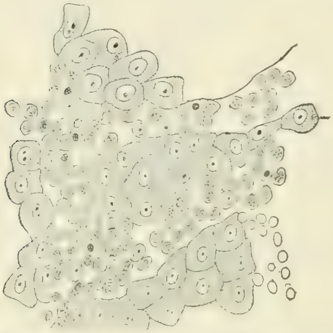

FIG. 509. Section of the Liver of a Fetal Cat, 2.7 cm., Showing the Development of the Liver Vessels and the Nucleated Red Corpuscles. To the right of the figure the newly formed vessel contains a number of non-nucleated red corpuscles. (After Howell.)

The formation of red blood corpuscles in the spleen is demonstrated by the presence in that organ of nucleated erythrocytes in considerable number from the fifth month of intra-uterine life until a few months after birth.

The share taken by the spleen in the formation of red blood corpuscles in the embryo is in any case an important one only during the latter half of intra-uterine life, after the process of formation in the liver begins to abate and before the long bones are fully formed. The process of multiplication of erythrocytes in the spleen is probably identical with that above described in the case of the liver; it persists, though in much lessened degree, up to the end of fetal life, and even for a period thereafter which is variously stated by different observers as from two or three weeks up to as many months. Eventually the formation of red blood corpuscles in the spleen entirely ceases, according to most modern observers, and this process is afterward confined to the red marrow. It has been clearly shown that the nucleated erythrocytes in all stages of intra-uterine development increase in number by mitotic division, and the relative activity of different organs as seats of formation has been rated from the relative number of erythrocytes showing karyokinetic figures in any given part. At first the cells undergoing division are seen in the circulating blood; later they may be observed only in the liver, and do not occur, or only occasionally, in the blood in other parts of the body; still later they are found in great numbers in the spleen; but at the close of intra-uterine life and thereafter they are found but rarely in the spleen *save after extensive bleeding*, and are almost solely confined to the red marrow. This is an interesting confirmation of the order, stated above, in which the hæmatopoietic organs of intra-uterine life take up their functions.

The manner in which these nucleated erythrocytes are converted gradually into non-nucleated cells as embryonic life advances, is probably the same as that by which a similar change occurs in extra-uterine life, and hence the reader is referred to that section of the article for a discussion of the subject.

A mode of development of red blood corpuscles which is distinctly different from all those above described in that non-nucleated corpuscles are formed therein, was first observed independently by Schäfer and Ranvier as taking place in large cells of the connective tissue just before birth, or just after birth in the case of mammals born in an immature condition, such as the white rat.

The large connective-tissue cells in which this peculiar intracellular formation of blood discs has been observed were named angioblasts by Schäfer and vaso-formative cells by Ranvier. Schäfer describes this method of formation of blood discs somewhat as follows:

A portion of the protoplasm of the angioblastic cell acquires a reddish hue from the development of hæmoglobin, and after a time this pigmented substance separates in the form of globules within the cells, which at first vary in size from a minute speck up to globules of the diameter of a mature red blood disc or even larger; but later the globules become more uniform in size. At a later stage, the angioblastic cells become elongated and pointed at their ends, and processes grow out from them to join similar processes of neighboring cells. Vacuoles now form within the cells, and by enlarging coalesce to form a cavity filled with fluid in which the reddish globules, which are by this time becoming disc-shaped, float. Finally the cavity extends through the cell processes into those of adjoining cells, thus constituting a hollow network of communicating vessels which becomes united with blood-vessels already formed so as be a part of the vascular system. In this manner the blood discs formed as above described pass into the circulating blood.

This type of formation of blood discs in the mammalia is confined to the portion of intra-uterine life immediately preceding birth, but in a few mammals which are born in an immature condition it may be observed for a short period after birth. At a later stage, although new vessels are similarly formed in growing connective tissue, no blood discs are observed in the process of genesis within them. Quite recently Hayem claims to have observed blood platelets as well as blood discs within these vaso-formative cells of young connective tissue.

Little is known as to the formation or mode of growth of either blood platelets or leucocytes during embryonic life, but it is certain that both are present in the blood during the later stages of intra-uterine existence, and also that both appear at a much later period than the red corpuscles. In a human embryo of five months Howell found both white blood corpuscles and blood platelets, but both were present only in small numbers. The white corpuscles were of two kinds, as in the adult, one variety being of small size with a single vesicular nucleus resembling the lymphocytes, while the other kind was of larger size, faintly granular, and apparently with several nuclei or a fragmented nucleus.

According to Schäfer, the earliest white blood corpuscles of embryonic life are in all probability amœboid cells of mesoblastic origin which have wandered into the blood-vessels or lymphatics, where they either may be increased in number by similar additions or may multiply by division.

Löwit states that white blood corpuscles are also formed in the liver during a portion of embryonic life, but at a later stage than the red corpuscles. It will subsequently be pointed out that during extra-uterine life white corpuscles are chiefly formed in lymphatic tissue. The lymphatic glands commence to develop somewhat late in fetal life, and after this there is no doubt that they, like the somewhat more diffuse lymphatic tissue formed elsewhere before them, take up the function of supplying leucocytes by mitotic division of the amœboid cells which they contain. It has also been stated that leucocytes are formed in intra-uterine life in the intestinal epithelium or the tissue underlying it.

According to Ziegler, the white corpuscles may be regarded as separated cells of the mesoderm, and the lymphatic glands as portions of the mesoderm which retain in this respect their embryonic character, and accordingly throughout life give rise to fresh mesodermic cells (the white blood corpuscles) which are carried off in the lymph.

The fact that the leucocytes are not found in the circulating blood in the earlier stages of fetal life shows that these are not formed in those organs which generate the erythrocytes, and hence that they are not, properly speaking, intrinsic constituents of the blood, but rather have been added from without probably by the agency of the lymph-forming organs. At this stage amœboid cells are also to be found in the tissues outside the blood-vessels as well as in the circulating blood stream, and accordingly they may be looked upon as normal constituents of all tissues which are carried into the blood by the agency of the lymph stream, and then afterward circulate in the blood for a variable time.

Extra-uterine Formation of Blood Corpuscles.—The earliest view entertained with regard to the origin of the red blood corpuscles in extra-uterine life was that they developed from the white corpuscles. This view was first enunciated by Wharton Jones in 1846, who supposed that the red corpuscles were the modified nuclei of the white corpuscles. The formation of a red corpuscle from a white one, according to this observer, consisted in a disappearance of the protoplasm surrounding the nucleus and a development of hæmoglobin in the latter which took on the peculiar shape of the blood disc. Kölliker also supported the view that the red were formed from the white blood corpuscles, but gave an entirely different account of the mode of development. He thought, from a comparison in size, that the blood discs arose from the small uni-nucleated white corpuscles derived from the lymphatic glands, and claimed that these have frequently a yellowish tinge, probably due to the presence of hæmoglobin, and hence that they may develop into erythrocytes just as in the embryo, where, he states, the first nucleated cells found in the blood-vessels are originally colorless. Kölliker admitted that no transition stages could be satisfactorily demonstrated in the blood, and in part attempted to explain this as possibly due to the rapidity of the change in certain stages. He supposed that the chief acts in the change were the disappearance of the nucleus and the modification in shape of the protoplasm. He further admitted that the large multinuclear leucocytes probably did not undergo any such metamorphosis into red blood corpuscles. This theory was supported by many observers, and some described the appearance in the blood of transitional forms between the white and red corpuscles, especially under exceptional conditions, in which the rate of formation of red corpuscles might be expected to be increased, as, for example, after excessive hemorrhage or in leukæmia; while under opposed conditions, such as inanition, these transitional forms were said entirely to disappear. Thus Erb claimed to have observed certain red corpuscles which contained a fragmented nucleus or granules apparently of nuclear origin. He supposed that white corpuscles arose in the lymphatic glands and spleen and passed into the blood stream as small uni-nucleated cells with a scanty cytoplasm. The cell increased in size and then underwent two modifications, one of which consisted in the partial disappearance of the nucleus by fragmentation, and the other in the development of hæmoglobin in the cytoplasm, so giving rise to his observed transitional forms. Finally, the cell became somewhat smaller and took on the characteristic shape of the blood disc.

A later theory located the origin of the blood discs in the spleen, where they were supposed to be formed endogenously within certain large cells of the splenic pulp. This theory rested on the experimental observation that within these splenic cells blood discs could be observed in various stages of formation; but while this experimental observation is generally admitted to-day, it is taught by many observers that this indicates a destruction of effete red blood corpuscles within the organ, and not a building up of new ones. The stages of alteration within these erythroclastic cells present all the appearances of degradation in the irregular and broken outline of the corpuscles, and not those of new formation.

The chemistry of the spleen proteids also supports the view that there is such a breaking down of hæmoglobin within this organ accompanied by a conservation of the iron-containing portion of the hæmoglobin molecule, for the spleen is the richest organ of the body in iron-containing proteids other than hæmoglobin. A similar presence of proteids containing iron in the liver, as well as the formation of the bile pigments which are so closely related to hæmoglobin, indicates that chemical processes connected with the metabolism of hæmoglobin also occur in the liver cells. The fact first demonstrated by Schäfer, that the plasma of the splenic vein contains no free hæmoglobin, shows clearly that the chemical alteration undergone by the red corpuscles disintegrated in the spleen is a deep-seated one, and not merely a physical breaking up of the blood disc as a physiological organization.

The next important advance in our knowledge of the extra-uterine formation of red blood corpuscles was made independently and practically simultaneously by Neumann and Bizzozero in 1868, by the discovery of nucleated red blood corpuscles in great number in the red marrow of bone, which closely resemble those found in embryonic life, but differ in being present at all stages of the animal's subsequent life. This important discovery may be said to have completely revolutionized our knowledge of the subject, and it is now very generally believed that except under very abnormal conditions no red blood corpuscles are formed elsewhere than in the red marrow of bone, although there are still differences of opinion as to the origin of these nucleated erythrocytes of the red marrow, as to the way in which they increase, and as to the manner and place in which they alter so as to give rise to the perfected blood discs. The erythrocytes of red marrow are nucleated cells of very variable size which are capable of very active amœboid movement, but differ from ordinary leucocytes of blood or lymph, and also from the other leucocytic elements of the marrow itself, in that they are tinged a light yellow color in the fresh condition by the presence of hæmoglobin. These cells undergo division, as was first shown by Bizzozero, by karyokinesis, and in this way undoubtedly are largely if not entirely regenerated in the marrow. In most sections of red marrow karyokinetic figures are easily observed, of which the diaster is the most frequently occurring form. It is also stated that the number of cells undergoing such indirect division is enormously increased after severe hemorrhage, so illustrating the much-increased rapidity of formation of blood discs.

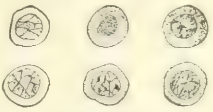

FIG. 510.—Nucleated Red Corpuscles, Showing the Mature and the Immature Forms, the Intermediate Stages, and the Colorless Erythroblasts. (Adapted from Howell.)

Howell divides the nucleated red blood corpuscles into immature cells and mature cells, according to the behavior of the nucleus toward chromatin-staining reagents. As extreme types he describes those containing in their nuclei a network of chromatin showing conspicuous, highly staining granules at its nodal points, and those in which the nucleus shows no reticular structure whatever, but takes a uniform stain as though the chromatin were evenly distributed throughout it (see Fig. 510). The latter is the more mature type; in it the nucleus is smaller than in the immature type, and, according to Howell, is being prepared for extrusion by being situated eccentrically, or indeed partially extruded. All shades of transition are to be found between the typically mature and immature types.

In addition to the nucleated erythrocytes, the red marrow contains other varieties of cells which are interesting here because they have been assigned by many observers a function as precursors of the nucleated erythrocyte stage of development.

That one of these to which much importance is generally attached as a forerunner of the erythrocyte is a leucocytic cell which cannot be said to differ in appearance in any respect from the immature nucleated red cell above described, save in that it contains no hæmoglobin. This type of cell has been described by Osler, Löwit, and others, and has been designated, from this supposed function, an erythroblast by Löwit. These cells must not be confused with ordinary leucocytes of the blood, also found in the marrow, and may be distinguished by the homogeneous appearance of their cell protoplasm, and, according to Löwit, by the fact that they never make amœboid movements nor ingest foreign particles.

The third type of cell seen in red marrow is what is termed the ordinary or proper marrow cell. This is somewhat larger than the other cells described above, and contains a prominent vesicular nucleus of oval shape showing one or two clearly marked nucleoli. In some varieties of this cell, according to Howell, the nucleus becomes elongated in shape and may be bent horseshoe-shape, or may even be coiled upon itself one or more times. Other cells, according to the same observer, may be detected in which the cell protoplasm is loaded with coarse granules.

In addition to these three types of cell of ordinary size the marrow contains a large number of cells peculiar to this tissue called giant cells; these are huge cells with only a single nucleus, which may be either notched or elongated and coiled upon itself so as to simulate the appearance of a number of nuclei. These cells are said by most authors to be different from the myeloplaques found near the developing bone, as well as in pathological formations under many conditions. The latter are multinucleated, and when found in bone marrow occur in such positions as to make the observer surmise that they are connected with bone absorption and accordingly are not intrinsic constituents of red marrow.

Many views are still maintained as to the origin of the nucleated erythrocytes of the marrow. One of the most important of these is that enunciated by Bizzozero, who, as above stated, first drew attention to the frequent occurrence of indirect division in these cells. This observer holds the view that the cells in question are direct descendants of the similar embryonic cells described above as occurring in embryonic life, which are carried to the red marrow as soon as this begins to develop, and take on the hæmatopoietic functions which were up till then taken care of by the embryonic spleen and liver. In the red marrow these cells increase by karyokinetic division, and in this way replace that fraction of their number which is continuously being modified to pass into the circulation as blood discs. Bizzozero is of the opinion that no other mode of origin of nucleated erythrocytes has been demonstrated, and that such a mode of origin forms an adequate explanation. Accordingly he regards the smallest faintly pigmented erythrocyte as the first stage toward the formation of the blood disc in the red marrow, and considers that the other types of cells present take no part in the formation of the red blood corpuscles. This view, that the nucleated erythrocytes of the marrow form a type which is *sui generis*, is supported by Schäfer and other observers; but probably the majority of writers, while not denying that these cells when once formed can increase by indirect division, hold with Neumann that they originate from non-pigmented cells of the marrow. Most of those holding the latter view consider that the second type of marrow cell described above is the colorless predecessor of the erythrocyte of the marrow, and have described these cells independently under different names. Löwit terms them erythroblasts, and deprecates the common use of this term to describe their colored descendants, which, according to him, should be called nucleated erythrocytes. Neumann also objects to the term of erythroblasts for the nucleated hæmoglobin-containing cells of the marrow, contending that such a term is applicable only to the colorless forms which precede them.

Malassez states that the nucleated red blood corpuscles are derived from the proper marrow cells by these giving rise first to spherical cells of large size which do not readily stain, contain little or no hæmoglobin, and possess a very diffuse nucleus. These cells are termed protohæmatoblasts by Malassez, and give rise to the nucleated erythrocytes by passing through two or three stages of alteration in which the cell protoplasm becomes granulated, and the nucleus at first enlarges, becomes prominent and uniformly granular, but later decreases in size and shows a reticular structure. At the same time that these changes are progressing the cell becomes more and more deeply tinted with hæmoglobin and takes on the appearance of the nucleated erythrocyte.

Foà and Salvioli express the view that the first stage in the formation of the erythrocyte is one type of the giant cell, namely, that described by Bizzozero as the type with budding nucleus, in which the nucleus is not multiple but apparently made up of a convoluted string of nuclei still in connection with one another. This giant cell, which is termed an hæmatoblast by these authors, breaks up into a number of small hyaline cells by the separation of the compound nucleus into its constituent buds, each of which has a fragment of the original cell protoplasm attached to it. The hyaline cells later change to nucleated red corpuscles by the development of hæmoglobin. Osler derives the nucleated red blood corpuscles from colorless hyaline cells of 9 to 12 μ in diameter containing a finely granular nucleus, which in turn arise from small lymphoid elements (2.5 to 5 μ) resembling free nuclei but often showing a narrow border of cell protoplasm. A very similar view has been proposed by Obrastzow, who, however, believes that the free nuclei give rise both to erythrocytes and proper marrow cells. According to this author, the erythrocyte contains no nucleus in the living state, the apparent nucleus being a postmortem effect.

Howell combines most of these theories of origin of the mature nucleated erythrocyte by describing them as different consecutive stages in a rather lengthened course of development. We may, following this author, probably trace the stages in development backward as follows: The nucleated red blood corpuscles differ in structure with their age, and two extreme types may be distinguished—one mature and ready to be converted into a non-nucleated corpuscle, and one immature, as shown by the character of the nucleus and the amount of hæmoglobin. The immature corpuscle multiplies by karyokinesis, and the daughter cells sooner or later appear as mature nucleated corpuscles. The immature or young nucleated corpuscles are in turn derived from spherical colorless erythroblasts, having a definite histological structure and found in the marrow. These erythroblasts multiply by karyokinesis. The erythroblasts again are derived from larger embryonic cells, usually described in the adult as ordinary marrow cells.

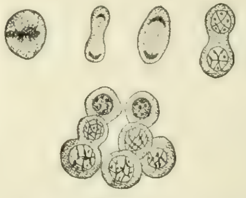

FIG. 511.—Multiplication of the Nucleated Red Corpuscles. Marrow of young kitten after bleeding. Showing above karyokinetic division of erythroblast, and below the formation of mature from immature erythrocytes. (Adapted from Howell.)

In these cells the structure of the nucleus differs from that of the erythroblast. The erythroblasts do not arise from these larger marrow cells in the same generation by a diminution in size, but the marrow cells multiply by karyokinesis, and the daughter cells of the first or following generations acquire the structure of erythroblasts.

There is also much diversity of opinion as to the manner in which the nucleated erythrocyte of red marrow becomes converted into the characteristic non-nucleated biconcave disc of mammalian blood. In fact all possible opinions have been presented by the ingenuity of various authors between the extremes that the red corpuscles are still nucleated, and that they are the nuclei of the nucleated corpuscles of which the cell protoplasm has disappeared. There is little doubt, however, that the non-nucleated corpuscle arises by the disappearance of the nucleus in some manner, and we need discuss here only a few of the chief ways in which it has been claimed that this disappearance of the nucleus is accomplished.

The earliest view and at the same time that which at the present day claims most adherents was originally expressed by Kölliker with regard to the nucleated embryonic erythrocytes, and was later extended by Neumann to include those cells discovered by him in the red marrow. According to this view the nucleus is gradually absorbed by the cell protoplasm after a previous partial fragmentation. "The cells gradually become more and more flattened, and even present slight excavations, whilst their nuclei manifestly diminish, and, on the application of acetic acid, exhibit a great tendency to disintegration. Ultimately, the *nuclei* disappear altogether and the blood cells become *non-nucleated*, like those of the adult, of which they all soon assume the form, being at first somewhat irregular" (Kölliker).

Neumann describes the nucleus as becoming smaller, more homogeneous, and later notched or indented, in the process of disappearing. He also describes certain cells containing only one or two granules of nuclear matter which he regards as the final stage in the disintegration and absorption of the nucleus. Another view which is supported by Rindfleisch, Howell, and others is that the nucleated cells become non-nucleated by a process of extrusion of the nucleus. The various authors who hold this view differ somewhat as to the manner in which the nucleus is expelled. Rindfleisch describes the nucleus as escaping from the cell surrounded by a small amount of colorless protoplasm, and leaving behind a residue of a reddish-yellow color, which is at first somewhat bell-shaped from the escape of the nucleus and afterward takes on the biconcave shape of the adult red blood corpuscle. For every red blood disc so formed there is in this manner set free in the circulation a colorless element, the further fate of which the author leaves unsettled. It is possible that it may once more form hæmoglobin in its cell protoplasm, which may increase in bulk and later give birth in similar fashion to a second non-nucleated red blood corpuscle.

Howell, on the other hand, states that the nucleus is extruded from the cell in a free condition and he has never been able to observe an envelope of protoplasm surrounding it as it escapes. Also free nuclei which have presumably been extruded from corpuscles are frequently seen in sections and teased specimens of red marrow. Howell admits that the homogeneous nucleus of ripe erythrocytes of the marrow may often be seen segmented or notched as described by Neumann, but as he has also seen similarly altered nuclei in the process of extrusion he holds that this segmentation does not prove that the nucleus disappears by absorption.

The extrusion of the nucleus can best be seen in teased specimens from the red marrow of animals which have recently been bled previous to killing and in which, therefore, the rate of formation of blood discs would naturally be much increased. All stages can be detected from that in which the nucleus has merely an eccentric position up to the period when it lies completely outside the cell.

It is well known that the nuclei are readily pressed out from the red blood corpuscles of amphibia after death by simple pressure of the cover glass or the action of chemical reagents, and Howell points out that the extrusion of the nucleus in the erythrocytes of the marrow cannot be any similar *artefact* for the following reasons: 1. The number of extruding nuclei is increased in animals which have previously been bled frequently. 2. The process of extrusion can be observed with the corpuscles in a perfectly fresh condition as soon as the specimen has been teased out in the animal's own serum. 3. Extrusion is seen when the cells have been fixed as rapidly as possible either by corrosive sublimate or by methyl green solution. 4. All the cells showing extrusion belong to Howell's mature variety (*vide supra*), for none of the extruding nuclei show any traces of a nuclear network. Still it is stated by Fellner, Osler, and other observers that the extrusion of the nucleus is to be regarded as a post-mortem change and that such extrusion does not occur under normal conditions in the living cell. Malassez denies that the nucleated red blood corpuscles lose their nuclei at all, maintaining that these retain their individuality throughout their life, but give rise to the red blood discs by a process of gemmation or budding. At some portion of the cell the cell protoplasm sends out a bud which enlarges, becomes constricted off from the rest of the cell, and is finally detached as a globule of hæmoglobinated protoplasm which afterward takes on the biconcave shape of the blood disc.

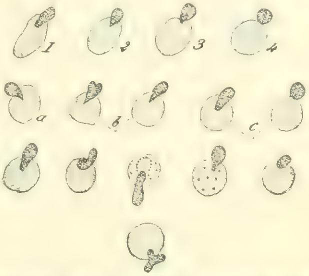

FIG. 512.—Shows the Way in Which the Nucleus Escapes from the Nucleated Red Corpuscles. 1, 2, 3, 4, represent different stages of the extrusion noticed upon the living corpuscles; *a*, specimen from the circulating blood of an adult cat, bled four times; *b*, specimens from the circulating blood of a kitten forty days old, bled twice; *c*, specimens from the blood of a fetal cat, 9 cm. long. Others from the marrow of an adult cat, two of the figures showing the granules present in the corpuscle which have been interpreted erroneously as a sign of the disintegration of the nucleus. (After Howell.)

With regard to the place of formation of the blood discs, it is almost universally admitted that the red marrow of bone is the tissue in which they are produced most abundantly. Neumann even maintains that this tissue is the only one which yields them, even under most exceptional circumstances, for their increased production, such as after excessive or oft-repeated blood-letting. Other observers, such as Bizzozero, hold that while the red marrow is the only seat of production under normal physiological conditions, yet other organs may take on the function of forming red blood corpuscles under abnormal conditions of increased production. Thus, nucleated red blood corpuscles have been found in the spleen of the dog and guinea-pig if the animals have previously been subjected to excessive bleeding (Bizzozero and Salvioli). Clinical observations also are on record in which it is stated that nucleated red corpuscles are found in the blood in severe cases of leukæmia or pernicious anæmia (Osler and Gardner). Howell has also observed a recurrence of the hæmatopoietic function of the spleen with regard to red blood corpuscles after excessive bleeding, although normally no nucleated red blood corpuscles are present in that organ.

Löwit and one or two other observers claim that both spleen and lymphatic glands are to be looked upon as blood-forming organs in addition to the red marrow. In all of these organs, according to Löwit, two kinds of colorless cells may be recognized which he terms "leucoblasts" and "erythroblasts" respectively, because the former give rise to the white and the latter to the red blood corpuscles. These two types of cell are distinguished by differences both in the action of their nuclei toward staining reagents, and in the mode of their division in reproducing new cells; also no intermediate forms between the two can be observed, showing them to be distinct types. The leucoblasts possess a prominent nucleus which contains one or more nodules of chromatin, usually of irregular outline, connected by delicate threads to the nuclear membrane. The after-fate of these is considered under development of white blood corpuscles. Division takes place by a movement of the chromatin granules from the equator toward the poles which Löwit proposes to call *divisio indirecta per granula*, to distinguish it from the true karyokinetic division which takes place in the erythrocyte and which he terms *divisio per fila*. The erythroblasts have a network of chromatin in their nucleus, and divide by ordinary karyokinesis; they never show amœboid movement nor ingest foreign particles; finally they develop hæmoglobin in their cell substance and so become nucleated erythrocytes.

In the marrow of bone always, and in the spleen under certain conditions above alluded to, transition stages may be observed, but in the lymphatic glands no intermediate forms between erythroblast and nucleated erythrocyte are ever to be seen, and hence Löwit supposes either that the transition in this latter case takes place in the lymph or blood stream or in both, or that the erythroblasts formed in the lymphatic glands are carried to the marrow and there undergo the final change into nucleated erythrocytes. Löwit further holds that a great number of the erythroblasts enter the blood stream from the spleen and lymphatic glands in a colorless condition, and are in the blood stream itself rapidly converted first into nucleated and later into non-nucleated erythrocytes. The two types of cells above described have also been observed subsequently by Denys and by Gibson, and the latter writer claims to have observed nucleated red blood corpuscles in the mesenteric lymphatic glands after ligature of the thoracic duct. Denys states that in the marrow of birds which has been double stained with fuchsin and methyl green, the nuclei of the erythroblasts stain green while those of the leucoblasts stain red. As a result of this distinctive staining the important fact is brought out that the two types of cell are not indiscriminately mixed, but that the erythroblasts occur in cords or strings forming the capillary portion of the vascular system of the marrow. A delicate endothelial wall marks off the cord of erythroblasts from the surrounding mass of leucoblasts.

Some observers state that red blood corpuscles develop in bone and cartilage, and particularly in the line of ossification between the growing bone and its hyaline cartilage, but this has again been denied by Neumann and others. Winogradow states that nucleated red corpuscles form in the lymphatic glands of the dog after spleen extirpation, but this result also has failed to obtain confirmation at the hands of other workers. Quite a different theory to all these is that supported by Hayem, in that it ascribes the origin of red blood corpuscles to the blood platelets or "elementary particles" of Zimmermann instead of the nucleated erythrocytes. This view was originally suggested by Zimmermann, but has been worked out in detail by Hayem, who has given more attention to the blood platelets than any other worker on the subject. Hayem describes the blood platelets as young red blood corpuscles and terms them hæmatoblasts. Certain of them, according to his description, are similar in shape to the biconcave discs, and possess a greenish tint from the presence of hæmoglobin. He claims to have observed intermediate forms between the typical blood platelet and the typical red blood corpuscle, and states that these transitional forms are greatly increased in number after severe hemorrhage when a more rapid regeneration of corpuscles is presumably taking place. Under such circumstances the blood platelets may increase so greatly in amount as to outnumber the red corpuscles.

There is also much difference of opinion as to the manner in which the blood platelets are formed. Pouchet, who supports Hayem's view that the red blood corpuscles are formed from the platelets, supposes that the platelets are either extruded from the white blood corpuscles as "polar bodies" or that they arise as concretions in the plasma. Gibson describes two varieties of platelet under the names of colorless and colored "microcytes." The former he supposes to be derived from the extruded nuclei of both nucleated red corpuscles and white corpuscles, and the latter (which he regards as identical with Hayem's hæmatoblasts) he supposes arise from fragmentation of mature blood discs in some manner in the circulation. Howell denies that the extruded nuclei of the erythrocytes give origin to blood platelets, showing that during the period that they persist in the blood as morphological elements, they stain quite differently from the blood platelets. It is probable, according to this author, that the extruded nuclei of the red blood corpuscles dissolve in the plasma, and possibly increase the percentage of fibrinogen therein. With regard to the origin of the blood platelets, Howell supports the view that they are the final products of disintegration of the multinucleated leucocytes, by drawing attention to the close resemblance between well-preserved blood platelets and the fragmented nuclei of the multinuclear leucocytes as far as size, shape, and general appearance are concerned. The resemblance is increased by the appearances noticed in the blood of an animal after frequent bleeding. Here blood platelets may be observed containing one or more deeply staining granules which closely resemble the chromatin granules of the nuclei, and are probably the result of too rapid expulsion of the nucleus on account of the increased activity in the blood connected with regeneration. The blood platelets further stain similarly to the nuclei when subjected to the action of multiple staining. Howell suggests that such disintegration of corpuscles within the plasma may have an important function in the regeneration of the proteids of that fluid.

It is almost universally agreed that the lymphocyte is the youngest form of leucocyte found in the blood. The lymphocyte is so termed because it is believed that it originates in lymphoid tissue and is added to the blood in the lymph stream.

The fact that the number of lymphocytes in the lymph is largely increased after its passage through a lymphatic gland, as well as the presence of immense numbers of similar cells in the lymphoid tissue, demonstrates that lymphocytes are formed in the lymphatic glands and are continuously carried away by the lymph and added to the circulating blood. Also in the blood white corpuscles are to be found which differ in no respect from these lymphocytes of the lymphoid tissues, and between these and the other varieties of leucocyte transitional cells are to be observed, so that there can be little doubt that all the other forms are stages in the further development of the lymphocyte.

Most observers also hold that leucocytes are formed in the spleen and red marrow in addition to the lymphoid tissues. Löwit describes the leucocytes as arising from certain cells in these tissues which he terms leucoblasts. The general characteristics which distinguish these from erythroblasts have already been stated; it may be added that Löwit describes the leucoblasts as entering the lymph stream and eventually reaching the blood as uninuclear leucocytes which are rather small and are devoid of the power of making amœboid movements. In the blood stream they increase in size while the nuclei take on the form seen in the polymorphonuclear cells; ultimately multinuclear leucocytes arise from these as a final stage which is followed by the disintegration and solution of the corpuscle. Löwit believes, from estimations of the relative number of the different forms of leucocyte in the blood coming from the blood-forming organs, in the right and left heart, and in the peripheral arteries, that the transition from the lymphocyte to the other forms takes place rapidly in the venous blood before reaching the left heart. Flemming and a great many other workers hold, in contradistinction to Löwit, that multiplication of the leucocytes takes place by a true mitotic division. It is certain also that the eosinophile cells of Ehrlich exhibit karyokinetic figures while undergoing division. Bannworth has described cells possessing all the properties of Löwit's leucoblasts, as undergoing karyokinetic division in the spleen pulp.

The life history of the leucocyte may then probably be described as follows: It arises from leucoblastic cells in lymphoid tissue and probably also in the splenic pulp and red bone marrow, and reaches the blood as a small cell, with a prominent vesicular nucleus surrounded by a trace of cell protoplasm. This variety of leucocyte is incapable of amœboid movement, but gives rise in process of growth to a large cell which is amœboid, and is further characterized by possessing a large envelope of finely granular protoplasm around its nucleus. In some varieties of this stage the granules in the cell protoplasm are more conspicuous than in others. The next development takes place by an alteration in the nucleus, which is no longer spherical or oval but drawn out into a strap or horseshoe shape, or indeed coiled or folded upon itself so as in some cases closely to resemble a multiple nucleus. This gives rise to the polymorphonuclear cell, which is still capable of amœboid movement, and which by fragmentation of the complex nucleus gives rise to the multinuclear leucocyte.

The earlier view was that the polymorphonuclear and multinuclear leucocytes were those in process of cell division, but it is now more commonly believed that the nucleus in these cells is undergoing fragmentation previous to the disintegration of the cell. *Benjamin Moore.*

The following references will be found to furnish a key to the source of most of the statements given in this article:

Bizzozero: Ueber die Bildung der rothen Blutkörperchen. Virchow's Arch., Bd. xcv., 1884, Sn. 26-45.

Brückner: Neuere Arbeiten aus dem Gebiete der Physiologie und Pathologie des Blutes. Schmidt's Jahrbücher, Bd. cclv., 1897, S. 62-69.

Hayem: Du sang et de ses altérations anatomiques, Paris, 1889.

Howell: The Life History of the Formed Elements of the Blood, especially the Red Blood Corpuscles. Journ. of Morphology, vol. iv., pp. 57-116.

Löwit: Die Anordnung und Neubildung von Leukoblasten und Erythroblasten in den Blutzellen bildenden Organen. Arch. f. mikr. Anat., 1891, Bd. xxxviii., Sn. 524-612.

Löwit, Minkowski, u. Andere: Verhandlungen des Congresses f. inn. Med., xviiter Congress, Wiesbaden, 1899, Sn. 134-213.

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Oppel: Unsere Kenntniss von der Entstehung der rothen und weissen Blutkörperchen (zusammenfassendes Referat). Centralblatt f. allg. Path. u. path. Anat., Bd. iii., 1892, Sn. 193-217 u. 241-259.

Schäfer: In Quain's Anatomy, tenth edition, 1893, vol. i., pt. ii., pp. 216-221 and 265-267.

BLOOD, NORMAL.—The blood would seem to conform to the general definition of a tissue, in that it is composed of a cellular and an intercellular substance. It differs, however, from any other tissue of the animal body in the fact that the intercellular substance is a fluid, and that it is a *moving* substance propelled by the beat of the heart throughout a system of closed tubes; it also, perhaps, contains a greater variety of morphologically and physiologically dissimilar elements than any other tissue; the blood, or its congener the lymph, is found in all structures, affording nourishment to them and taking in their waste products in return. There is no passage of morphological constituents from the general tissues into the blood as may sometimes occur from the blood to the tissues, as during diapedesis.

According to the same standard, the lymph would seem to come within the limits of the definition, although it is poorer in cellular elements. Whether certain of the semi-fluid secretions, such as the orchitic and mammary during the colostrum period, might come within the range of this definition, we may perhaps regard as unsettled, although it is a question if the fundamental procedure is not analogous when we consider the relationship of the leucocytes to the lymph glands and that of the red corpuscles to the bone marrow and certain other organs.

The total number of cells in the body has been estimated by C. Francke* to be 26,500,000,000,000, of which 4,000,000,000,000 are fixed cells, while the cells in the blood are not fixed, and according to the best calculations these amount to 22,500,000,000,000. So that the cells in the blood, which are small, outnumber those of the other tissues (some of which, for example the muscle cells, are relatively immense) about five and one-half times.

Blood in general has for its functions (*a*) the conveyance of nutritious material to all parts of the body, (*b*) to remove waste products from the tissues, (*c*) to carry oxygen for tissue (or internal) respiration, and (*d*) to equalize the temperature of the body.

Color and Constituents.—Blood has the appearance of a red, slightly viscous fluid, this effect being due to the suspension of innumerable microscopic bodies, the red corpuscles or erythrocytes, in a clear yellowish fluid, the plasma or liquor sanguinis. In addition to the red corpuscles, but much less numerous, are the white corpuscles or leucocytes. A third element is the blood platelet, a small discoid colorless particle, demonstrable microscopically in freshly drawn blood. There may also be blood granules of different kinds, considered as transformation products of the formed elements.

The color of arterial blood is a bright red, that of the veins is darker or of a bluish-purple tint. This difference is due to the relative amount of oxygen or carbon dioxide present. Arterial blood furthermore differs from venous in that it possesses more O, less CO_2, more extractives, more salts, more sugar, less urea, and is usually warmer.

Arterial blood becomes dark when respiration is imperfect, for example, in the fœtus, during anæsthesia by chloroform, when the trachea is compressed, and in individuals when submitted to a high temperature (which reduces the excretion of CO_2). Venous blood is rendered brighter in animals which have been made to breathe pure oxygen, or when poisoned by carbon monoxide gas, in blood leaving glands in a state of secretory activity or muscles in a state of rest (Bernard), and in hibernating animals.

In the pulmonic circulation the arteries normally contain dark, and the veins bright red blood.

Odor.—Blood has an odor which differs in man and animals. This is thought to be due to the presence of certain volatile acids. If concentrated sulphuric acid be added to blood it liberates these acids from their combinations with alkalies, and the characteristic odor is more perceptible.

Taste.—Blood has a saline taste, due to the various salts dissolved in the plasma.

Temperature.—Blood varies normally in its temperature from 36.5° to 37.8° C. (97.7° to 100° F.). It varies also in different parts of the body. The warmest blood in the body is in the hepatic vein. The blood of the left is cooler than that of the right ventricle, because as it passes through the lungs it is cooled by the inspired air. The blood of the skin is also slightly cooler than that of the viscera. In the arteries, however, it is, as a rule, slightly warmer than in the corresponding veins.

Amount.—The amount of blood in the body has usually been determined by drawing a measured amount, defibrinating it, and diluting portions of it in differing degrees for later comparison. The rest of the blood is then collected and defibrinated, and the vessels washed out with salt solution until the solution comes out colorless. The washings are added to the collected blood, and this is further diluted until it corresponds in tint to one of the previous samples of known dilution. The total quantity of blood in the vessels can then be calculated. In addition to this the whole body can be minced into fine pieces, extracted with water to get any blood that may still remain in the tissues, and this also be added to the mass of blood. Some hæmoglobin, however, is yielded by the muscles.

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* "Die menschliche Zelle," 1891.

Another method, used by Gréhant and Quinquand, is to determine the amount in the living animal. A measured amount of carbonic oxide (mixed with oxygen) is inspired. A measured amount of blood is then drawn off and the amount of carbonic oxide in this quantity is determined. The amount of the gas in the total blood of the body would be in the same proportion as in the sample, from whence the whole amount of the blood can be calculated.

From these methods it is estimated that the blood is equal to from one-eleventh to one-fourteenth of the body weight (about 12 pounds in a man weighing 154 pounds).

In the newly born child the amount of blood is estimated at one-nineteenth of the body weight. This proportion will vary, however, according to the time of ligaturing the umbilical cord.

The amount of blood in different organs may be estimated by quickly tying their blood-vessels *intra vitam*. An aqueous extract of the minced organ is prepared and the quantity of blood estimated as previously described. A rough approximation of the division of the blood in the body by this method gives one-fourth to the lungs, heart, and large blood-vessels, one-fourth to the skeletal muscles, one-fourth to the liver, and the remaining one-fourth to the other organs.

Less blood will be obtained from a fasting animal than from one which has digested a hearty meal. This fact is probably one of the causes of the discrepancies in the figures given by different investigators.

REACTION.—The alkalinity of the blood may be recognized in spite of its red color by applying a drop of it to the surface of glazed litmus paper. Or still another method is to soak a strip of ordinary litmus paper in salt solution and allow it to dry. Apply a drop of blood to this and it will be found that the substance upon which the alkalinity depends will diffuse itself around the drop and give the characteristic color to the litmus.

To the presence of the carbonate and phosphate of soda is attributed the alkaline reaction. This is undoubtedly true for the plasma, but it is questionable if these salts account for it in the corpuscles as well, where it is probably due to the presence of organic substances of a weak basic nature.

Saturation of the blood with carbonic acid causes the corpuscles to become less, and the plasma more alkaline.

The alkalinity of the blood seems to vary during the day, being lowest in the morning and gradually rising in the afternoon, and becoming lower again in the evening. It also rises during digestion. Muscular work diminishes it, especially if there is little or no proteid in the diet; while with a diet rich in proteids there is very little alteration. It is also diminished after withdrawal, and during the process of coagulation. The alkalinity is also decreased in fever and in many diseases. In diabetic coma and in the cold stage of cholera an acid reaction has even been detected. The decrease in alkalinity is accompanied by a diminished amount of carbonic acid in the blood. The acid reaction frequently occurring in menstrual blood may be due to the uterine mucus and vaginal acids.

SPECIFIC GRAVITY.—The specific gravity of normal blood varies within small limits. For men it ranges from 1.057 to 1.066; for women from 1.054 to 1.061. It is slightly less in children than in adults, but is higher in the fœtus than in the mother; it is highest in the child at term, in which it is 1.066, while that of the maternal blood is then only about 1.050. In the ox and dog it is about 1.066. In a given case in a man in whom the specific gravity of the blood was found to be 1.060, the corpuscles gave a specific gravity of 1.088[*] and the plasma, 1.031.

The specific gravity of the blood is lowered slightly when much fluid is ingested, and increases somewhat after profuse perspiration. It varies also according to the part of the body from which it is taken, subject perhaps to accidental admixture with lymph. Blood from the finger has been found to be slightly lower than that obtained from the skin over the shin.

The variations in age and sex are closely related to the variations in the amount of hæmoglobin. The specific gravity of blood from an artery is nearly the same as that from the corresponding vein.

The blood of birds has a higher specific gravity than that of mammals, and there has also been noted in the latter slight variations in different species.

The method commonly used for determining the specific gravity of blood is known as Roy's method; it consists in transferring minute drops of blood to a mixture of glycerin and water, or some similar mixture which is mixed in varying proportions to form a series in which the specific gravities are known. The mixture in which the drop of blood neither rises nor falls gives the specific gravity of the blood.

The analysis of blood as given by Hammarsten follows, 1,000 parts being taken:

	PIG BLOOD.		OX BLOOD.		HORSE BLOOD.		DOG BLOOD.		HUMAN BLOOD, MAN.		HUMAN BLOOD, WOMAN.	
	Blood corpuscles, 435.09	Serum, 564.91	Blood corpuscles, 325.5	Serum, 674.5	Blood corpuscles, 397.7	Serum, 602.3	Blood corpuscles, 442.8	Serum, 557.2	Blood corpuscles, 513.02	Serum, 486.98	Blood corpuscles, 396.24	Serum, 603.76
Water	272.20	518.36	192.65	616.25	243.87	551.14	277.71	514.30	349.69	439.02	272.56	551.99
Solids	162.89	46.54	132.85	58.249	153.84	51.15	165.10	42.89	163.33	47.96	123.68	51.77
Hæmoglobin	142.20	......	103.10	..	125.8	.....	145.6	.....				
Proteid	8.35	38.26	20.89	48.901	20.05	42.65	2.36	34.05				
Sugar	.....	.684	.....	.708	......	.90	.....	.74	Organic			
Cholesterin	.213	.231	1.100	.835	.26	.31	.56	.37	bodies			
Lecithin	1.504	.805	1.220	1.129	1.93	1.05	1.02	.98	159.59	43.82	120.13	46.70
Fat	.....	1.104	...	.625	......	.50	......	.91				
Fatty acids	.027	.448	.....	...	.2	.36	....	.70	Inorg.			
Phosphoric acid as nuclein	.0455	.0123	.0178	.0089	.5	.01	.05	.01	3.74	4.14	3.55	5.07
Soda		2.401	.7266	2.9084	......	2.62	1.27	2.39	.24	1.66	.65	1.92
Potash	2.157	.152	.2351	.1719	1.32	.15	.11	.14	1.59	.15	1.41	.20
Iron oxide	.696	.....	.544	......	.59	......	.71					
Lime	......	.0689	.	.0805	......	.07	......	.06				
Magnesia	.0656	.0253	.0056	.0300	.04	.03	.03	.03				
Chlorine	.642	2.048	.5901	2.4889	.18	2.20	.60	2.31	.90	1 72	.36	.14
Phosphoric acid	.8956	.1114	.2392	.1646	.98	.15	.67	.14				
Inorganic P_2O_5	.7194	.0296	.1140	.0571	.76	.05	.54	.05				

RED BLOOD CORPUSCLES.—Swammerdam in 1658 was the first to discover red blood corpuscles in the frog. Malpighi in 1661 was the first to describe them in a mammal (hedgehog), and in 1673 Leeuwenhoek demonstrated their presence in man.

Red blood corpuscles differ in shape and size in different groups of animals. In all mammals they are nonnucleated in the adult. With the exception of the camel family, in which they are of elliptical form, they present a circular outline and are biconcave. In birds, reptiles, amphibia, and fish they are nucleated, elliptical, and biconvex. An exception to the elliptical form is noted in the *Marsipobranchii*, as represented by the lamprey eel, in which they are circular but nucleated. In man the average diameter is between 7 and 8 microns and 1.9 microns thick at the edge; in the frog the long diameter is about 22 microns; in the *Proteus* about 60 microns, while in the *Amphiuma*, where the corpuscles can be distinguished with the unaided eye, the long diameter is about 80 microns.

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[*] The specific gravity of the red corpuscles is usually given at 1.105.

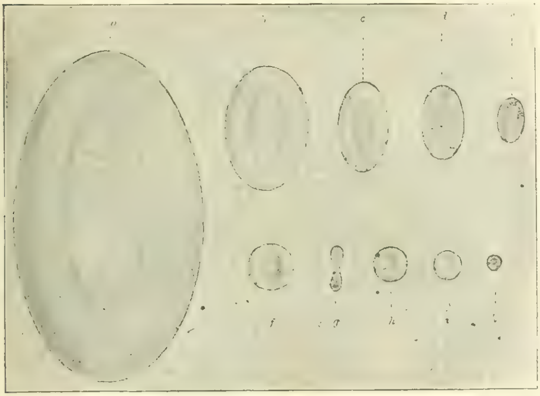

FIG. 513.—Red Blood Corpuscles of Different Vertebrate Animals. (Welker's models; from Boehm and von Davidoff.) × 1,000 diameters. *a*, From Proteus (salamander); *b*, from the frog; *c*, from a lizard; *d*, from a sparrow; *e*, from a camel; *f* and *g*, from the human being; *h*, from myoxus glis (dormouse); *i*, from a goat; *k*, from the musk-deer.

The relatively larger size of the corpuscles in the so-called cold-blooded animals than in mammals is an interesting fact, and has served as a basis for some investigations to determine the effect of climate upon the size of the corpuscles of the inhabitants. Evidence on this point is conflicting. According to Hamilton the measurements of the corpuscles of representatives of the following nationalities gave the subjoined list.

Italians	7.0-7.5	microns.
French	7.5-7.6	"
Germans	7.8	"
Norwegians	8.5	"

Differences in size, as reported by different observers, are probably due to different standards of measurement. Parker, taking the average measurement of 500 corpuscles, obtained the following results:

Italian, seventeen years old	7.79	microns.
American girl, seventeen years old	7.90	"
Girl from Finland, twenty-five years old	7.89	"
Esquimaux girl	8.07	"

It is interesting to note that the measurement of the corpuscles of the girl from Finland is less than that usually given for Norwegians, although she came from a higher latitude.

The specific gravity of the red corpuscles, usually given at 1.105, is susceptible to variation according to osmotic currents between the corpuscle and the plasma, the currents being determined by the composition of the plasma. One cubic millimetre of blood contains .000397 gm. of moist red corpuscles; 1 litre, 397 gm.; and an adult man having 5 litres of blood in his body has nearly 2 kilograms (4.4 pounds) of red corpuscles. The total mass of red cells in 5 litres of blood, in round numbers, is put at 25,000,000,000,000. The total length of these cells would be in the neighborhood of 175,000 kilometres (109,370 miles), more than four times the circumference of the earth (Viault et Jolyet). The total surface of the corpuscles (including the two faces and edges) would be equal to 2,816 square metres (more than half an acre). This immense amount of surface is exposed to and absorbs oxygen as the blood circulates through the lungs. This oxygen-absorbing surface decreases in different animals, other things being equal, with the size of the corpuscle. It diminishes from the mammals to the batrachians.

The elasticity of the corpuscle is feeble but perfect. It permits these cells to pass through capillaries narrower than their own diameter, and later to regain their original form. They have, however, no inherent power of contractility, except, perhaps, in the embryonic condition. Carbon dioxide causes them to lose their elasticity and distorts them.

The property of adhesion of the corpuscles, already recognized by Hewson in 1770, refers to the arrangement of the corpuscles in *rouleaux*. It occurs either in blood drawn from the body, or in blood stagnant in the vessels. This phenomenon appears to be due to a beginning alteration in the structure causing a greater viscosity of the surface of the corpuscle.

In blood drawn from the vessels the corpuscles change their form quite rapidly on account of the exosmosis of their salts, becoming quite markedly crenated. Cold, heat, electricity, water, and various chemical reagents cause this change. Bile and the biliary salts render the corpuscles pale and later dissolves them (Kühne). Urea acts similarly. Urine acts like saline solutions, causing the corpuscles to swell and dissolving their coloring matter, making it difficult to see them.

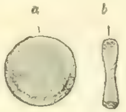

FIG. 514. Red Blood Corpuscles of Man. *a*, Surface view of normal corpuscles; *b*, edge view. (After Boehm and von Davidoff.)

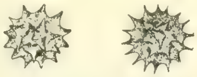

FIG. 515.—Crenated Blood Corpuscles (Human). × 1,500 diameters. (After Boehm and von Davidoff.)

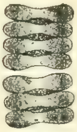

FIG. 516.—Blood Corpuscles (Human) in Rouleaux, like pieces of coined money. × 1,500 diameters. (After Boehm and von Davidoff.)

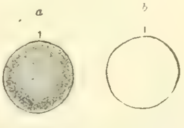

FIG. 517.—Red Blood Corpuscles (Human) as They Appear After They have been Subjected to the Influence of Water. × 1,500 diameters. (After Boehm and von Davidoff.) *a*, swollen, but with color still retained; *b*, swollen and decolorized ("blood-corpuscle shadows").

In some cases the serum from an animal from a different species causes swelling, distortion, and destruction of the red corpuscles. In the transfusion of blood from one animal to another of a different species there is quite likely to occur a reciprocal destruction of the transfusing and transfused corpuscles.

Two views exist as to the structure of the red corpuscle: that of Rollet, in which it is believed that a spongy and elastic framework or stroma exists holding the hæmoglobin; the other is that revived and maintained by Schäfer, namely, that the corpuscle consists of a delicate but resistant external envelope enclosing colored fluid contents, or, in other words, a solution of hæmoglobin.

The corpuscles are at times subjected to considerable pressure and often become markedly distorted. They are, however, remarkably elastic bodies, and it is due to this physical property of the stroma or envelope that the normal shape is regained.

The organic matter in one hundred parts of dried blood is as follows:

	Human.	Dog.	Goose.
Proteids and nuclein	5.10-12.24	12.55	36.11
Hæmoglobin	94.30-86.79	86.50	62.25
Lecithin	.35- .72	.59	.46
Cholesterin..................	.24- .25	.36	.48

The higher percentage of proteids in the goose's blood is due to the included nuclein, which is usually the case in nucleated red corpuscles.

The mineral constituents vary greatly in different species of animals. In man potassium constitutes 40.89 per cent. of the total ash of the red corpuscles and sodium only 9.71 per cent. In the dog the percentage of potassium is 6 07 and of sodium 36.17. In the plasma there is a large excess of the sodium over the potassium salts.

Origin and Fate of the Red Corpuscles.—A corpuscle, like the body itself, has an allotted time of activity and then disintegrates. All red corpuscles, even of mammals, are nucleated at a certain period of development. In the human fœtus at about the fourth week, all of the red corpuscles possess nuclei. These corpuscles gradually diminish in number, however, until at birth they have nearly or quite disappeared. The nuclei are extruded or absorbed and the non-nucleated condition characteristic of adult mammals appears. In the rat, which is born in a somewhat immature state, many of the red corpuscles may be found to be nucleated for a short time after birth. The first corpuscles formed in the embryo (chick, guinea-pig) are entirely outside the body. Even before the heart has begun to beat there are certain mesoblastic cells in a zone, the "vascular area," around the embryo, which send out long, anastomosing processes, soon assuming a hollow form—the capillary blood vessels. At the same time groups of nuclei, formed by the division of the original nuclei of the cells, assemble at the nodes of the network. There is a bit of protoplasm around each nucleus, which soon develops hæmoglobin in its substance, and the newly formed corpuscles float away in the newly developed vessels.

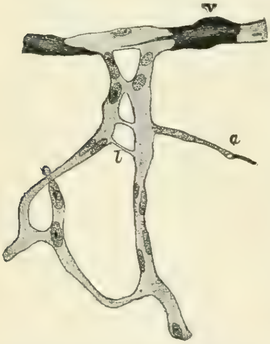

FIG. 518.—Developing Capillary Blood-Vessels from the Tail of a Tadpole (After Klein.) v, Capillary vein with clumps of pigment in the wall; *a*, nucleated protoplasmic sprout; *l*, solid anastomosis between two neighboring capillaries.

Later on, during embryonic life, the nucleated corpuscles seem to be developed, in part at least, in the liver, spleen, red bone marrow, and the blood, by division of the nucleated corpuscles themselves.

After birth the chief seat of development of the red corpuscles in mammals seems to be the red marrow of the bones of the skull and trunk and of the ends of the long bones of the limbs. The formation of red corpuscles is also known under the name of hæmatopoiesis. In this marrow there are special nucleated, feebly amœboid cells, originally colorless, which multiply by karyokinesis, and are transformed by various stages into the ordinary non-nucleated red corpuscles, which are washed away in the blood stream. Such blood-forming cells have received the name of erythroblasts or hæmatoblasts.

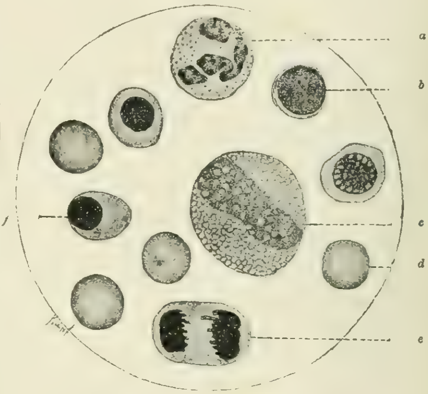

FIG. 519.—From the Bone Marrow of the Dog. × 1,200 times. (From Boehm and von Davidoff, after H. F. Müller.) *a*, Mastzelle; *b*, lymphocyte; *c*, leucocyte with acidophile granules; *d*, non-nucleated blood corpuscle; *e*, nucleated red corpuscle in the act of dividing; *f*, nucleated red corpuscle.

The loss of the nucleus and the fact that hæmoglobin is the parent substance of the bile and urinary pigments, and that these pigments are constantly being excreted, render it certain that the life of the red corpuscle cannot be a long one. Just how long this life is, and where and how the corpuscles go to pieces, has not yet been fully determined.

It has been suggested that the spleen is especially concerned in this destruction from the fact that a certain amount of iron is found there, and that in histological preparations of teased spleen tissue certain large cells have been found which contain red corpuscles in various stages of disintegration. It has been supposed that the large cells have ingested the red corpuscles, presumably selecting those which are in a weakened condition. Some hold, however, that this may be a post-mortem phenomenon, because, since the blood flow has stopped, the corpuscles lie at rest, while the amœboid movement of the leucocytes continues—a state of affairs which would be favorable for ingestion. Still more important is the fact that complete removal of the spleen does not seem materially to lessen the normal destruction of the corpuscles.

Turning to the liver, in which the bile is formed, it is noteworthy that although no iron is found in the bile, there is an abundance of it in the cells of the liver. It would seem, therefore, that the iron must be removed from the hæmoglobin, or one of its derivatives, by the liver cells, and the pigment material carried away by the bile. It would appear that although the corpuscles are destroyed in the liver to a considerable extent, they may meet a like fate in the spleen, in the red bone marrow under some pathological conditions, and even in the blood itself.

It is interesting to note that some of the organs in the adult, which are concerned in the destruction of the corpuscles, have a totally opposite action in the embryo—being then the seat of their origin.

Number of Red Corpuscles.—The average normal number of red corpuscles in the adult male is commonly given at 5,000,000 per cubic millimetre; in the female, at 4,500,000. There are, however, numerous normal conditions which increase or decrease this number. It varies in individuals with the constitution, nutrition, and manner of life; age is also a factor, the number being greater in the fœtus and newly born child; there is a decrease after meals. In the female, the number varies in menstruation and in pregnancy, being somewhat increased in the former and diminished in the latter. The influence of high altitudes in increasing the number of corpuscles is an interesting fact. It has been shown that a residence of two or three weeks in high mountains will cause an increase in the blood of from 2,000,000 to 3,000,000 corpuscles per cubic millimetre. It would seem to follow from this that a diminished pressure of oxygen in the atmosphere stimulates the corpuscle-forming tissue to a greater activity. The diminution in oxygen pressure probably results in a diminished oxygen supply to the tissues, including the red marrow, and as a consequence the hæmatoblasts are stimulated to greater activity. This change in the number of corpuscles is naturally related to a difference in the amount of hæmoglobin, and is probably an adaptation for insuring a normal oxygen capacity for the blood.

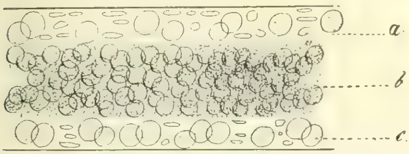

FIG. 520.—Diagram Showing Relation of the Solid Portions of the Circulating Blood to the Walls of the Blood-Vessel. (After Eberth and Schimmelbusch.) *a*, Blood plaques or third corpuscles; *b*, red corpuscles; *c*, white corpuscles.

The above explanation is, perhaps, equally applicable when a considerable amount of blood has been lost during hemorrhage. Experience has shown that the blood rapidly regains its normal condition and that the corpuscles are manufactured quickly to replace the drain that has been made upon their numbers. The anæmic condition undoubtedly causes a diminution in the oxygen supply to the corpuscle-forming tissue and the hæmatoblastic cells are stimulated to more rapid multiplication.

With reference to the influence of altitude upon the corpuscles, there are some who ascribe the apparent increase of the corpuscles to other reasons than those mentioned, namely, that there is an increased evaporation from the general surface, and thus a loss of water from the blood; that there is an increased arterial tension, increasing the amount of lymph, which also assists in giving a higher concentration of the blood, and thereby an apparently larger number of corpuscles. Weiss experimented upon this point by keeping some rabbits at a high altitude for about four weeks, and compared them with animals at lower levels. He found an increase of corpuscles to the extent of twelve to twenty-four per cent., but no absolute increase of hæmoglobin in the whole body.

HÆMOGLOBIN.—Hæmoglobin is a very complex, iron-containing crystalline coloring matter, which forms the most important constituent of the red corpuscles, and in virtue of which they perform their functions as the oxygen carriers of the organism. This substance possesses the property of linking to itself a molecule of oxygen, so as to form an easily dissociated compound, which is termed oxyhæmoglobin, to distinguish it specifically from the coloring matter which has parted with its oxygen. This is termed by many hæmoglobin, although numerous others prefer to call it reduced hæmoglobin.

Both oxyhæmoglobin and reduced hæmoglobin invariably (Hüfner) exist side by side in varying proportion in the living blood; the former being most abundant in arterial, and the latter in venous blood.

It has hitherto been held that the hæmoglobin of the blood normally combined with the oxygen, and that the carbon dioxide was held by the plasma in combination with soda as sodium carbonate and sodium bicarbonate. The combination is very feeble in both cases—easily made and unmade. It is true that carbon dioxide is present to a large extent in the plasma, but that some of it is also taken up by the hæmoglobin is now quite well demonstrated. In a mixture of O and CO_2 each gas is absorbed by hæmoglobin solutions independently of the other, so that such a solution nearly saturated with oxygen can unite with as much CO_2 as though it held no oxygen in combination. It has been suggested by Bohr that the O and CO_2 may unite with different portions of the hæmoglobin, the O with the pigment portion, and the CO_2 with the proteid portion. The exact value of hæmoglobin as a carrier of CO_2, as compared with the plasma, has not yet been accurately determined.

Hæmoglobin constitutes about 40.4 per cent. of the weight of the moist corpuscles, and about 95.5 per cent. of all the organic substances contained in them.

The question as to the form and manner in which the hæmoglobin is retained in the corpuscle is an extremely difficult one to solve. It has been held by some that it is in solution either by the liquid contents of the corpuscle or by combining with other constituents. Others hold that it is in a solid or semi-solid condition either in a crystalline or in an amorphous form. The following facts bear more or less directly upon this matter.

The blood corpuscles as compared with the other soft parts of the body contain a relatively smaller proportion of water. According to Bunge the corpuscles contain 36.7 parts of solids and 63.3 parts of water; muscular tissue contains about 25 per cent. of solids and 75 per cent. of water; nerves contain about 22 per cent. of solids and 78 per cent. of water. The amount of water in the corpuscle seems insufficient to hold the hæmoglobin in solution. Moreover, in some animals the hæmoglobin is so sparingly soluble that it is said that the whole of the water in the blood would not suffice to dissolve the hæmoglobin stored up in the corpuscles.

On the other hand it is shown that the hæmoglobin does not exist in the blood corpuscles in the form of minute crystals, by the use of crossed Nicol prisms, as doubly refractive particles, while experimentally hæmoglobin crystals, reduced to the finest state of division, do show this appearance. The highest powers of the microscope also fail to show any crystalline or granular structures in the corpuscles.

Against the view that hæmoglobin goes into solution in combination with other constituents, *e.g.*, alkalies, potassium, etc., is offered the argument that if such were the case the plasma of the blood, which also contains these substances, would dissolve the hæmoglobin; and this, as is well known, does not occur. Taking the view, however, that the hæmoglobin is in solution within the envelope of the corpuscle (Schäfer's idea), this solution in the plasma could not normally occur on account of the indiffusibility of hæmoglobin through an unaltered membrane. Another assumption, advanced by Hoppe-Seyler and very generally accepted, is that the hæmoglobin exists in some combination with the stroma of the corpuscle, possibly lecithin. Gamgee assumes that the combination is with an as yet unknown constituent of the corpuscle. This compound, whatever it may be, is characterized by remarkable instability, for it is easily decomposed, setting free the hæmoglobin. This goes into solution when the plasma or serum in which the corpuscles are suspended is diluted, or when such substances as ether, chloroform, or biliary salts act upon the corpuscles. Heat, alternate freezing and thawing, and induced electrical shocks bring about the same result.

Although the coloring matter of the blood in different species of animals behaves in the same manner with reference to its combining with gases to form more or less easily decomposable compounds, and although it possesses identical powers in absorbing the rays of the spectrum, the hæmoglobin in different animals shows differences in crystalline form, in solubility, in the quantity of water of crystallization, and in percentage composition. The hæmoglobin in the blood of the rat, guinea-pig, and squirrel crystallizes most readily; next in order is that of the cat, dog, and horse; while that of the rabbit, sheep, ox, and the frog crystallizes with considerable difficulty. On the other hand the hæmoglobin of the rat, guinea-pig, and squirrel goes into solution with difficulty; while that of man and the domestic herbivorous animals is easily soluble.

Hæmoglobin is a compound of carbon, hydrogen, nitrogen, sulphur, iron, and oxygen. The crystals of hæmoglobin contain water of crystallization, which varies in different animals. When ignited, pure hæmoglobin obtained from mammalian blood yields an ash composed entirely of ferric oxide; that of birds and fishes, and probably from all animals possessing nucleated corpuscles, yields an ash which, in addition to Fe_2O_3, contains phosphoric anhydride (P_2O_5), derived, probably, from the nuclein contained in the corpuscles.

According to Preyer the average percentage composition of 100 parts of hæmoglobin is as follows:

C	54.00
H	7.25
N	16.25
Fe	.42
S	.63
O	21.45
	100.00

On the theory that the molecule of hæmoglobin contains one atom of iron, Preyer assigned to it the empirical formula $C_{600}H_{960}N_{154}FeS_3O_{170}$, the molecular weight being 13.332.

In the analysis of the hæmoglobin of the dog, Jaquet has calculated the following percentage composition:

C	53.91
H	6.62
N	15.98
S	.542
Fe	.333
O	22.62

with a molecular formula of $C_{758}H_{1203}N_{195}S_3FeO_{218}$, which would make the molecular weight 16.669.

The question naturally arises, Why should there be such an extremely high molecular weight? A very suggestive explanation has been offered by Bunge as follows:

"The enormous size of the hæmoglobin molecule finds a teleological explanation; if we consider that iron is eight times as heavy as water, a compound of iron, which would float easily along with the blood current through the vessels, could only be secured by the iron being taken up by so large an organic molecule."

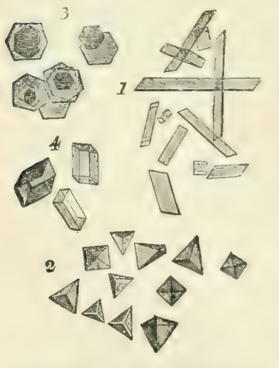

FIG. 521.—Oxyhæmoglobin Crystals Magnified. 1, From human blood; 2, from the guinea-pig; 3, squirrel; 4, hamster. (Halliburton.)

Form of Oxyhæmoglobin Crystals.—The blood of man and of the majority of animals yields crystals in the form of rhombic prisms or needles belonging to the rhombic system. Those from the blood of the guinea-pig, as shown by von Lang, are in the form of tetrahedra belonging to the rhombic system. The blood of certain birds and occasionally of the rat gives crystals of the same form. The oxyhæmoglobin of the squirrel crystallizes normally in the form of six-sided plates belonging to the hexagonal system.

Amount of Water of Crystallization.—The difficulties attending an investigation of this kind are very numerous and discouraging. The usual procedure is to dry pure oxyhæmoglobin *in vacuo* at 0° C., and after it ceases to lose weight to heat it to a temperature of 115° C. The following table shows some of the most reliable results obtained.

Oxyhæmoglobin.	Water of crystallization, per cent.	Authority.
Dog	3.4	Hoppe-Seyler.
Horse	3.94	Hüfner.
Pig	5.9	Otto.
Guinea-pig	6	Hoppe-Seyler.
Squirrel	9	Hoppe-Seyler.

Solubility.—The oxyhæmoglobin of all birds, of the ox, pig, and man, is readily soluble, the solubility increasing in the above order. Next in order of solubility is that of the horse, dog, squirrel, guinea-pig, and rat, the latter being the least soluble.

The difference in solubility is supposed to be due to differences in the amount of the albuminous residue.

Oxyhæmoglobin is soluble in dilute solutions of ammonia and other caustic alkalies, and their carbonates. It is also soluble in very dilute alcohol. On the other hand it is insoluble in absolute alcohol, chloroform, benzol, and carbon disulphide.

Diffusibility.—Oxyhæmoglobin is an exceptional example of a soluble crystalline body, which from its inability to pass through a septum of parchment paper is considered to be absolutely non-diffusible. This characteristic is dependent upon the immense size of its molecule.

Absorption Spectra.—Solutions of hæmoglobin and compounds derived from it give distinctive absorption bands when examined with the spectroscope. In order to obtain satisfactory results very dilute solutions of oxyhæmoglobin must be used. When they are examined with the spectroscope two absorption bands appear, both occurring in the portion of the spectrum included between the Fraunhofer lines D and E. The band nearer the red end of the spectrum is known as the "α-band," and is narrower, darker, and more clearly defined than the other, the "β-band." With a solution containing 0.09 per cent. of oxyhæmoglobin, and examined in layers 1 cm. thick, the α-band extends over the part of the spectrum included between the wave lengths λ 583 (583 millionths of a millimetre) and λ 571, and the β-band between λ 550 and λ 532 (Gamgee). The width and distinctness of the bands vary with the concentration of the solution used. With a minimal percentage of oxyhæmoglobin (less than 0.01 per cent.) the β-band is lost and the α-band becomes very faint. With stronger solutions the bands become darker and wider and finally fuse, while some of the extreme red end and a great deal of the violet end of the spectrum are also absorbed. The absorption which takes place as the concentration of the solution increases affects the red orange end of the spectrum last of all.

Solutions of reduced hæmoglobin show only one absorption band, known as the "γ-band." This band lies also in the portion of the spectrum included between the lines D and E. The γ-band is much more diffuse than the oxyhæmoglobin bands, and its limits, especially in weak solutions, are not well defined; in solutions of blood diluted 100 times with water, which would give a hæmoglobin solution of about 0.14 per cent., the absorption band lies in the part of the spectrum included between the wave lengths λ 572 and λ 542. The width and distinctness of this band vary also with the concentration of the solution. In this case, the last light to be absorbed is partly in the red end and partly in the blue, thus explaining the purplish color of hæmoglobin solutions and of venous blood. Oxyhæmoglobin solutions can be converted to reduced hæmoglobin solutions, with a corresponding change in the spectrum bands, by placing the former in a vacuum, or, more conveniently, by adding reducing solutions. Those most commonly used for this purpose are ammonium sulphide and Stoke's reagent. The latter is made by dissolving 2 gm. of ferrous sulphate in 100 c.c. of distilled water, adding 3 gm. of tartaric acid and making faintly alkaline by the addition of ammonia. This solution should be used fresh. If a solution of reduced hæmoglobin is shaken with air, it quickly changes to oxyhæmoglobin, and gives two bands instead of one when examined through the spectroscope. This is an easy way of showing the facility with which hæmoglobin takes up and surrenders oxygen.

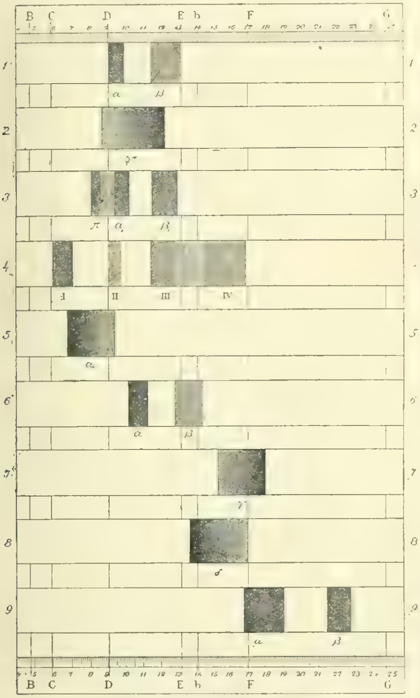

FIG. 522.—Spectrum. 1, Absorption spectrum of a solution of oxyhæmoglobin; 2, absorption spectrum of a solution of hæmoglobin, obtained by the action of an ammoniacal ferro-tartrate solution on an oxyhæmoglobin solution; 3, absorption spectrum of a faintly alkaline solution of methæmoglobin; 4, absorption spectrum of a solution of hæmatin in ether containing oxalic acid; 5, absorption spectrum of an alkaline solution of hæmatin; 6, absorption spectrum of an alkaline solution of hæmochromogen, obtained by the action of an ammoniacal ferro-tartrate solution on an alkaline hæmatin solution; 7, absorption spectrum of an acid solution of urobilin; 8, absorption spectrum of an alkaline solution of urobilin after the addition of a zinc chloride solution; 9, absorption spectrum of a solution of lutein (ethereal extract of the egg yolk). (Hammarsten.)

Solutions of carbon monoxide hæmoglobin also give a spectrum with two absorption bands closely resembling in position and appearance those of oxyhæmoglobin. They are distinguished, however, by being slightly nearer the blue end of the spectrum. Furthermore, a solution of carbon monoxide is not reduced as is oxyhæmoglobin, by the addition of Stoke's fluid; the two bands still persist. A solution of carbon monoxide may be easily prepared by passing ordinary coal gas or illuminating gas through a dilute oxyhæmoglobin solution for a few minutes and then filtering.

Compounds Derived from Hæmoglobin.—*Methæmoglobin* is obtained by the action of oxidizing agents on hæmoglobin. It is frequently found in blood stains or pathological liquids containing blood, which have been exposed to the air for some time. It is practically the same as oxyhæmoglobin, except that the oxygen is in a firmer combination. It crystallizes in the same form as oxyhæmoglobin, but has a different and characteristic spectrum.

Hæmatin ($C_{32}H_{32}N_4FeO_4$) is obtained when oxyhæmoglobin is decomposed by acids or alkalies in the presence of oxygen. It is amorphous and has a spectrum peculiar to it.

Hæmin ($C_{32}H_{32}N_4FeO_4HCl$) is a compound of hæmatin and HCl, and is easily obtained in crystalline form. The crystals are very characteristic and are readily obtained from blood clots or blood stains, even if not recent. In medico-legal cases involving the detection of blood this form of crystal is the one usually sought for.

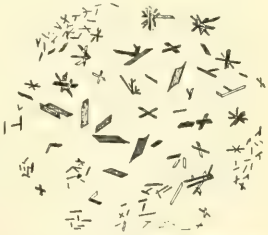

FIG. 523.—Hæmin Crystals Magnified. (Preyer.)

Hæmatoporphyrin ($C_{32}H_{36}N_4O_6$) is obtained by the action of strong sulphuric acid on hæmatin. It is characterized by the absence of iron.

Hæmochromogen is obtained by decomposing hæmoglobin with acids or alkalies in the absence of oxygen. It crystallizes and has a characteristic spectrum.

Hæmatoidin ($C_{16}H_{18}N_2O_3$). This name was applied by Virchow to a crystalline substance found in old blood clots, formed, without doubt, from the hæmoglobin of the clotted blood. It has been shown to be identical with one of the bile pigments—bilirubin. It shows no definite absorption band in its spectrum, but causes a general absorption of the ultra-violet, violet, and blue rays.

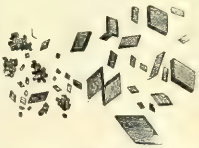

FIG. 524.—Hæmatoidin Crystals.

Bile and Urinary Pigments.—Hæmoglobin is considered to be the parent substance of the urinary as well as of the bile pigments.

"LAKY BLOOD" is the term applied to the blood when the hæmoglobin has escaped from the corpuscles and becomes dissolved in the plasma. Normal blood with the hæmoglobin enclosed in the corpuscles is opaque even in a very thin layer, whereas laky blood in thin layers is transparent.

A sufficient disturbance of equilibrium or osmotic relations between the corpuscles and surrounding medium will cause this escape of the hæmoglobin. Blood may be made laky by the addition of distilled water, acids, alkalies, heat, ether, chloroform, bile or bile salts, by alternate freezing and thawing, by the serum from the blood of another animal, electricity, and numerous other methods.

Isotonic Solutions, as applied to the blood, refer to liquids containing soluble substances with an attraction for water, in quantities sufficient to prevent the imbibition of water by the red corpuscles. The liquid must be concentrated enough to prevent the absorption of water by the corpuscle. A certain amount of water exists normally in the corpuscle. If the concentration of the surrounding liquid is diminished this equilibrium is disturbed and water passes into the corpuscle; enough water may pass into it to cause swelling and ultimately the discharge of the hæmoglobin, thus producing laky blood.

A solution containing a lesser percentage of salt or other soluble substance than suffices to keep the hæmoglobin is known as "hypisotonic"; while a solution containing a greater percentage of salt than will preserve the equilibrium is known as "hyperisotonic." The essential fact is an alteration of the permeability of the corpuscle either by the solution or mechanically, so that the hæmoglobin, or one or more of its constituents, diffuses itself into the surrounding fluid.

In isotonic solutions the concentration varies according to the substance used. Thus a solution of sodium chloride from 0.64 to 0.9 per cent., or of sugar 5.5 per cent., or of potassium nitrate 1.09 per cent., is isotonic to the corpuscles, or, at least, the latter do not imbibe water sufficient to cause them to discharge their hæmoglobin. The isotonic relations of certain substances have been quite well worked out for the red blood corpuscles; but it seems reasonable that the other cells of the body have likewise an isotonic relationship with fluids coming in contact with them; and speaking generally, it may be said that normal blood and lymph are isotonic to the various tissue elements, and must be kept so in order to avoid pathological conditions.

White Blood Corpuscles or Leucocytes.—These elements were discovered by Hewson in 1770. They are uncolored bodies possessing the power of amœboid movement, are often of a spherical form, and are slightly larger but much less numerous than the red corpuscles. The investigations of Ehrlich, Schultze, and others have shown that there are at least three different forms of leucocytes present in the blood, corresponding, perhaps, to three stages in their development: (1) A small spherical cell, with scanty protoplasm and a relatively large nucleus, amœboid movement very doubtful. They are called lymphocytes because they resemble the leucocytes found in lymph glands and are supposed to be brought into the blood through the lymph. (2) Mononucleated leucocytes. They possess a greater amount of cytoplasm, are of a finely granular character, and have some power of amœboid movement. (3) Polynucleated or polymorphous leucocytes. They are large, irregular in form, finely granular, and possess a lobulated nucleus or as many as four separate nuclei. They have very pronounced amœboid movements, and form about 70 to 75 per cent. of the white corpuscles.

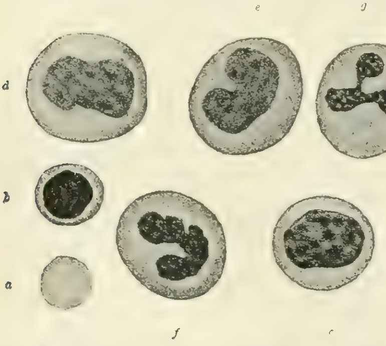

Fig. 525.—Leucocytes from Normal Human Blood × 1,200 diameters. (From Boehm and von Davidoff, after H. F. Müller.) *a*, Red blood disc; *b*, small mononuclear leucocyte; *c*, large mononuclear leucocyte; *g*, leucocyte with a nucleus of very irregular shape; *d*, *e*, *f*, leucocytes representing transitional forms between *c* and *g*.

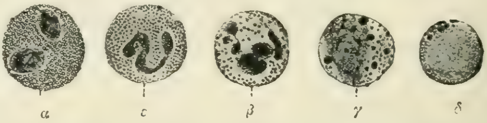

Fig. 526.—Ehrlich's Granules in Leucocytes. × 1,200 times. α, acidophile granules, relatively large and regularly arranged; ε, neutrophile granules; β, amphophile granules, not numerous and irregularly arranged; γ, mastzellen with granulations of unequal size; δ, basophile granulations. α, δ, and ε, from normal blood; γ, from leukæmic blood of man; β, from the blood of the guinea-pig. (From Boehm and von Davidoff, after H. F. Müller.)

Other classifications have been made, based upon microscopic structure and reaction to stains. Ehrlich divides the leucocytes into three groups, according to the size and the staining of the granules found in the cytoplasm. The *oxyphiles* or *eosinophiles* or acidophiles are those leucocytes in which the granules stain only with acid aniline dyes—*i.e.*, where the acid portion of the dye acts as the stain (eosin, picric acid, aurantia). The *basophiles* are those in which the granules stain only with basic dyes (dahlia, acetate of rosanilin). The *neutrophiles* are those in which the granules stain only with neutral dyes (picrate of rosanilin). A later paper by Kanthack and Hardy states that the neutrophile granules of Ehrlich are in reality oxyphile granules. In human blood they find the finely granular oxyphile cells (neutrophile and amphophile cells of Ehrlich) make up 60 to 80 per cent. of the whole number of leucocytes, the lymphocytes (and hyaline cells) (basophile granules) 20 to 30 per cent., and the coarsely granular oxyphile cells (eosinophile cells of Ehrlich) less than 5 per cent., but these proportions are far from constant.

Ehrlich's classification is perhaps more suitable for pathological than for normal conditions of the blood.

It is said that the eosinophiles and neutrophiles are relatively few in normal blood. Eosinophile granules occur in the polynucleated cells. These cells are greatly increased in leukæmia. The basophile granules occur also in connective-tissue corpuscles, especially in the neighborhood of epithelium; they are always greatly increased where chronic inflammation occurs. The large polynucleated amœboid cells found outside the vessels in inflammations exhibit a neutrophile reaction. Neutrophile granules are not found in the lymphocytes nor in the mononuclear cells. It is questionable if such a classification even for pathological conditions is wholly satisfactory, since no definite function for the granules has yet been established, and it is still undetermined whether the specific granules are permanent or temporary structures.

It is indeed a question if the different forms of leucocytes are distinct histological elements having independent origins and different functions, or whether they do not, after all, represent different stages in the development of a single kind of cell, the lymphocytes representing an early and the polynucleated leucocytes the last stage.

Specific Gravity.—Leucocytes have a lighter specific gravity than the red corpuscles, as is shown when the blood clots slowly, as it does normally in some animals, *e.g.*, the horse. The red corpuscles, on account of their greater density, sink to the bottom, while the leucocytes, being much lighter, form the upper portion of the clot.

Number.—The leucocytes average about 1 for every 500 of the red corpuscles, or 10,000 per cubic millimetre in man and 9,000 per cubic millimetre in woman. The number will vary under different conditions. They are increased after digestion, hemorrhages, pregnancy, in diseases in which suppuration occurs, and in leucocythæmia, in which disease they may equal even the red corpuscles.

Conditions which diminish the number of leucocytes are fasting, old age, and the action of certain medicines.

Leucocytes are more numerous in the capillaries and veins of the spleen, liver, glands, and intestinal mucosa than in the corresponding vessels of the skin, muscles, and general cellular tissue. Leucocytes are also more numerous in the blood of the newly born—about 19,000 per cubic millimetre (Hayem).

The chemical constituents of leucocytes are variable and difficult to analyze with accuracy. Lilienfeld, who has carried on investigations along this line, gives the following quantitative composition:

Water	88.51
Solids	11.49
Proteid	1.76
Nuclein	68.78
Histon (proteid part of nucleo-proteid)	8.67
Lecithin	7.51
Fat	4.02
Cholesterin	4.40
Glycogen	.80

Pus cells are leucocytes which show a considerable amount of fatty degeneration and are generally dead.

Functions.—The functions of leucocytes are various; some theories formerly accepted are now advanced with doubt, among which may be mentioned the assistance supposed to be rendered in the absorption of peptones and fats. Recent and careful experiments point toward the intestinal epithelial cells as the important factor in this process. Peptones appear to be converted into coagulable albumin during their passage through the epithelium, as practically no peptone is found in the blood or chyle. It has likewise been quite satisfactorily demonstrated that by far the greater amount of fat is likewise taken up by the epithelium and but little, if any, by the leucocytes.

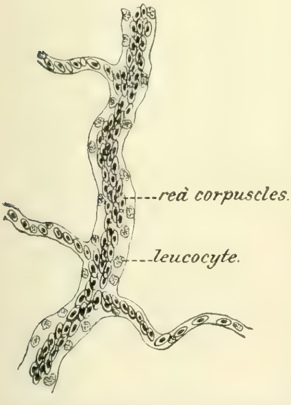

FIG. 527.—A Vein (Frog), As It Appears When the Current Begins to Slow. The red corpuscles remain in the central portion of the blood stream, while the leucocytes creep slowly along the wall of the vessel, sticking here and there. (After Craig.)

Leucocytes, or their products, are an undoubted factor in the coagulation of blood. Further details will be discussed under Coagulation.

One of the most peculiar properties of leucocytes is their power of independent movement, in virtue of which they are often called "wandering" cells. A leucocyte may be considered in some ways as a typical cell formed of unmodified protoplasm, wholly unspecialized and potentially equivalent to a unicellular animal, *e.g.*, an amœba. Movement is accomplished by the pushing out of a portion of the cell substance to form a pseudopodium; this may be retracted, and other pseudopodia formed, and in this way the corpuscle may move or "flow" from place to place, and envelop or ingest such particles as come in its way. This form of motion was first noticed in the amœba, and is therefore called amœboid in the leucocyte. In a certain sense *body* corpuscles would be a more appropriate term than leucocytes; for they or similar cells are found in many locations and wander everywhere in the spaces of the connective tissue.

They pass into the blood-vessels with the lymph, and pass out of them again in virtue of their power of amœboid movement. This process of migration occurs normally, but is greatly increased under certain pathological conditions. This phenomenon of migration is known as diapedesis (discovered in 1846 by Waller), and is especially prominent when a vascular part is irritated, causing dilatation and congestion of the vessel. The leucocytes then begin to adhere to the wall; they accumulate and finally pass through, probably *between* the endothelial cells of the capillaries. After this emigration they may wander away, or become organized and form new tissue (Waller), or they may accumulate, degenerate, and form pus. Red corpuscles are also sometimes seen to pass through the walls. Leucocytes may, however, play another part, namely, the repair of injured tissues. A clean healthy wound is soon covered with a layer of lymph, which is largely composed of white corpuscles. If repair progresses in a healthy manner the leucocytes may become organized and assist in the development of connective tissue, forming the cicatrix by which the wound is closed.

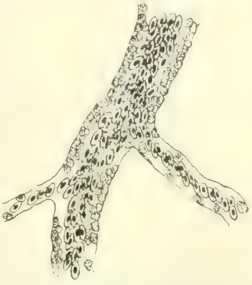

FIG. 528.—Showing a Vessel in Which the Current has Nearly Come to a Standstill. The leucocytes are arranged in rows along its wall. (After Craig.)

Certain amœboid cells of the blood, lymph, and splenic pulp are able to ingest or "eat up" foreign particles with which they may come in contact. This process is known as phagocytosis, and the cells are therefore known as phagocytes. This term, however, does not include all leucocytes nor does it exclude all other cells, as some fixed cells—*e.g.*, the endothelial cells of blood-vessels—show phagocytic properties by being able to send out protoplasmic processes, while, on the other hand, the small immobile lymphocyte is not a phagocyte. Although the phenomenon of phagocytosis has not as yet as exact a physiological value as some other processes, there is little doubt but that it plays an important rôle in the defence of the organism from outside invaders, as, for example, pathogenic bacteria, etc. This action of the phagocytes is of very great interest and importance. Metschnikoff, from his investigation upon the lower as well as the higher organisms, has added much useful information to science. He found that in some instances the leucocytes were victorious over the invaders, the latter being ingested and destroyed. In other cases the invaders were successful, by poisoning, weakening, overpowering by larger numbers and ultimately destroying the leucocytes. Metschnikoff supposed that the immunity to certain diseases, possessed normally by some animals and conferred on others by vaccination with certain protective substances, is due largely to the success of the phagocytes in the fight with the bacteria. More recent investigations show that Metschnikoff's phagocytic theory of immunity requires some modification, at least for man and the higher animals, although some of the observations upon which his theory was built still retain their value. He concluded that in order to confer immunity, the leucocytes underwent certain changes and acquired a kind of "education" which enabled them to fight bacteria against which they were previously helpless. It seems in the light of the more recent investigations that the substances which can confer immunity may be present not only in the leucocytes, but in other cells as well, and even in the serum Such substances have the power to destroy, or at least inhibit, the growth of bacteria.

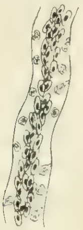

FIG. 529.

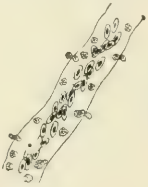

FIG. 530.

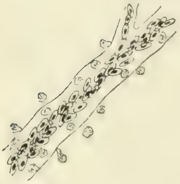

FIG. 531.

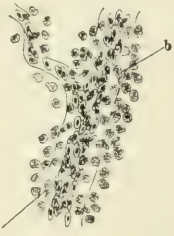

FIG. 532.

FIGS. 529 TO 532.—FIG. 529.—Leucocytes sending forth processes which penetrate the wall of the vessel. (After Craig.) FIG. 530.—Leucocytes partly through vessel wall, showing constriction in centre. (After Craig.) FIG. 531.—Leucocytes after penetrating wall regain former shape. (After Craig.) FIG. 532.—Appearance of vessel and surrounding tissue after diapedesis has gone on for some time. (After Craig.)

Correlated with the question of phagocytosis is the question of the ultimate fate of the particles ingested by the leucocytes. This matter has been investigated by Miss E. J. Claypole in amphibia (*Necturus* and *Cryptobranchus*) and by Berry in some of the mammals (rat, rabbit, and dog), the latter corroborating in all important respects the statements of the former. A further important function of the leucocytes, as scavengers of the body, is suggested. Miss Claypole says: "Considering the leucocytes as scavengers of the animal body in addition to their other functions, if their individual fate is inseparable from that of the waste material which they contain, they themselves must become waste material when their active functions cease, and must ultimately disappear from the organism. In the first place, they wander from the circulation through the tissues to the epidermal and mucous surfaces (amphibia), and are carried away with the other waste products of the body; in the second place, they are destroyed in the spleen by the splenic cells. The large numbers found in various stages in the first condition and the relatively large number of ingested spleen cells prove that the destruction of leucocytes is by no means insignificant."

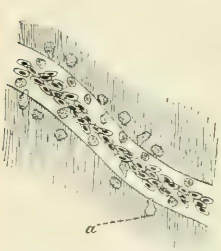

FIG. 533.—Small Vein of Mesentery. Showing the arrangement of the granules during and after penetration of wall by the leucocyte. (After Craig.)

Maurel takes the view that the different forms of the leucocytes are merely the intervening stages in their development. He does not accept the view that leucocytes multiply in the blood. He has seen what he terms apparent division of the corpuscle, one portion budding off from the parent substance but still connected by an almost invisible strand, and later a complete reunion of the two portions. According to his classification there are three main types: 1. A small, colorless and immobile leucocyte, evidently corresponding to the lymphocyte of other writers. 2. The second type consists of five forms of leucocytes, all of which are characterized by the power of displacing a larger or smaller amount of their substance and possess a greater or less degree of mobility. They differ in respect to their granularity. 3. Two forms, one very granular, immobile, and deformed; the other showing beginning signs of disintegration.

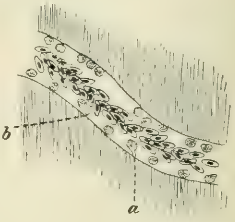

FIG. 534.—Small Vein in Mesentery. Leucocytes sending off a process clear of granules (*a* and *b*). (After Craig.)

The above types represent the periods of development and decay; the second type representing the active life of the corpuscle.

In determining the effect of temperature upon the leucocytes of the human blood, Maurel found that at about 25° C. (77° F.) movements as evidenced by displacement of their cellular substance were generally manifested. Between 25° and 16° C. these displacements were very feeble, and at 16° they ceased. If this temperature, however, was of short duration and gradually raised the movements would return. At 14° C. (57° F.) life disappeared from the corpuscles completely. He concludes that a temperature of at least 25° is required to cause satisfactory movements in the cells and that the above temperature is essential for the occurrence of diapedesis. Between 25° and 32° C. the displacement of substance is very slight. From 32° to 39° C. the movements are very marked. From 39° C. (102° F.) to 43° C. (109° F.) the maximum degree of activity occurs. Above 44° C. (111° F.) the life of the corpuscle is very quickly menaced, and at 45° C. (113° F.) the leucocyte takes on a spherical form and dies in a short time. The temperature as usually taken (axilla, etc.) is supposed to be one to two degrees lower than the internal temperature (liver, etc.), so that from the above figures, the greatest activity of the leucocytes in the human body takes place at the normal and during a febrile state of medium intensity. In animals of dif-

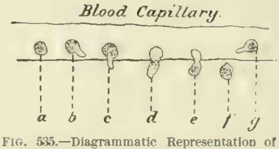

FIG. 535.—Diagrammatic Representation of the Manner in Which a Leucocyte Traverses the Wall of a Capillary Blood-Vessel. (After Craig.) *a*, Leucocyte before penetrating; *b*, leucocyte sending off process and granules beginning to withdraw to farther end of cell; *c*, leucocyte partly through wall, granules at upper end of cell; *d* granules passing through the wall; *e*, granules arranged in the portion of the leucocyte farthest from vessel; *f*, leucocyte, after penetration, resuming its original condition; *g*, leucocyte swept from wall, showing retention of the clear penetrating process.

ferent species in which the temperature is normally different from that of man, the variations in the activity of the leucocytes are correlated with the temperature of that species of animal.

In addition to studying the power of resistance exhibited by the leucocytes with respect to extremes of temperature, Maurel has also investigated their power of resistance against certain physical and chemical agents and drugs. As with temperature, the leucocytes of different species will react differently toward the agents just mentioned. He found that while human leucocytes are sensitive to cocaine and very much so to atropine, those of the rabbit were only one-third as sensitive to cocaine and not at all to atropine. The leucocytes of the frog will absorb certain pathogenic bacteria with impunity, while those of the rabbit and man will not absorb them, but are rapidly killed.

Horbaczewski has called attention to the fact that uric acid originates chiefly from the nuclein of disintegrated leucocytes, and the greater the number of leucocytes in the blood the greater is the destruction of the same, and hence the elimination of uric acid is correspondingly increased. Observations on the elimination of uric acid harmonize with this theory. In leukæmia, where there is an abnormally large number of leucocytes, the elimination of uric acid is greatly increased. Those drugs which increase the number of leucocytes also increase, in general, the elimination of uric acid.

Origin of Leucocytes.—It is evident that leucocytes are formed largely in lymph glands, from the fact that the lymph leaving such glands is much richer in corpuscles than the lymph coming to the glands. The fact that lymph coming to the glands contains leucocytes indicates that, although some of them may get into the lymph by diapedesis, other parts are also concerned in their production, *e.g.*, diffuse adenoid tissue, or special collections of it such as the tonsils, Peyer's patches, and the solitary follicles in the intestine, and the splenic corpuscles. To a small extent the white corpuscles may multiply in the blood by karyokinesis. The latter method may perhaps occur more generally in the so-called cold-blooded animals than in mammals.

The fate of the leucocytes is much less easy to ascertain than that of the red corpuscles from the fact that the former contain no such pigment as hæmoglobin or other substance that would assist in following the path of their destruction. It is not improbable that some of the leucocytes undergo disintegration in the blood itself and that their constituents aid in maintaining a proper proteid equilibrium. It has been shown by the work of Miss Claypole and of Berry that many of the leucocytes are undoubtedly destroyed in the spleen, and it is not at all unlikely that other localities are also involved in this process. That they are constantly breaking down is certain, for they are constantly being produced.

Blood Platelets or Plaques.—The *Blutplättchen* (Bizzozero) or hæmatoblasts (Hayem) are small, circular, sometimes irregular bodies appearing nearly homogeneous in structure and varying in size (0.5 to 5.5 microns). They average about 3 microns in diameter and are always smaller than the red corpuscles. Hayem's view that they are hæmatoblasts or precursors of the red corpuscles is now considered erroneous. Their number in the blood has been variously estimated from 180,000 to over 600,000 per cubic millimetre. Taking 400,000 as the average number, they would be forty times as numerous as the leucocytes and about one-twelfth as numerous as the red corpuscles. Although there has been a great amount of histological research upon the platelets, very little is known of their function or chemical composition. It is generally believed that they are not independent cells. In drawn blood they disintegrate almost immediately; this fact prevented their discovery for a long time after the blood had been studied microscopically. To study them, the blood must be drawn at once into some fixing solution (osmic acid, etc.). They can be seen, however, in capillary blood-vessels which have just been removed from animals, in which the blood is still fluid and the constituents therefore still alive. They have not been found in lymph. According to Löwit they consist chiefly of a globulin and play an important part in fibrin formation (coagulation). Lilienfeld from a chemical standpoint considers that they consist of nucleo-proteid, a substance like that obtained from the nuclei of leucocytes. From this ground, some take the view that the platelets are derived from the nuclei of the leucocytes, and that when the multinucleated forms go to pieces the fragments of the nuclei persist for a longer or shorter time in the blood as platelets and are eventually dissolved in the plasma. The special function of the platelets, beyond that of assisting in coagulation, still remains to be discovered.

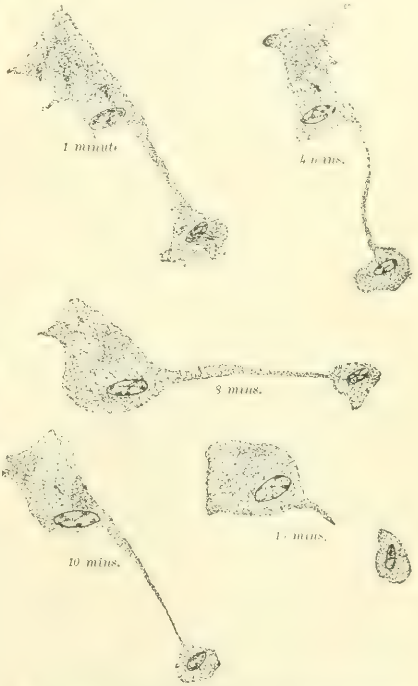

FIG. 536.—Figures of a Leucocyte Undergoing Division (Amphibia). (After Claypole.)

Fibrin.—When blood coagulates there separates from it an albuminous substance, which is nearly insoluble. This substance is fibrin, and remains in the clot. If coagulation is prevented by whipping the blood, the fibrin adheres to the rods of the whip in the form of elastic threads or fibrin masses. These may be washed free from the adhering corpuscles by using a stream of water. While wet the fibrin has a white, stringy appearance, later drying into an irregular mass. The threads which compose fibrin, as seen in a microscopic preparation of blood, interlace with one another and form a fine network, which entangles the blood corpuscles in its meshes. These have a strong tendency to retract, and explain why a clot shrinks and squeezes out the serum from its interior.

Fibrin exists in the lymph as well as in the blood.

The blood of mammals and of amphibia, as shown by Gage, exhibit an interesting difference in regard to the fineness of the constituent threads. In the frog (*Necturus* and *Cryptobranchus*) the threads are relatively very much finer than those in mammals, requiring careful observation with a one-twelfth-inch oil-immersion objective. A very interesting and important fact has been brought out in connection with the formation of fibrin in amphibians and birds. Semmer has shown that after the usual amount of fibrin has formed in the blood from frogs or domestic fowls (also true of *Necturus* and *Cryptobranchus*), additional fibrin is formed by the addition of a solution of sodium or magnesium sulphate. After all of the fibrin had been removed in the customary way and the source of it eliminated as far as possible by whipping the blood and pouring off the serum and white corpuscles, when the salt solution was added additional fibrin appeared, which seemed to differ in no way from the original fibrin. Experiments carried on in exactly the same way upon the blood of mammals failed in every instance to develop any extra fibrin, from which it is concluded that the additional fibrin, in the cases cited, was due to certain substances contained in the nucleated red corpuscles, these substances having been liberated by the solvent action of the salt. A probable explanation of this phenomenon would seem to be that in all nucleated red corpuscles nucleo-proteid material is present; in non-nucleated corpuscles this material is absent or very slight in amount. As the nucleo-proteids are believed to be essential in causing the blood to clot (see under *Coagulation*), we can readily understand that the additional supply of nucleo-proteid set free from the disintegrated nucleated red corpuscles could assist in the formation of more fibrin. Since the non-nucleated corpuscles contain none or an insufficient amount of the nucleo-proteid material, no additional clotting or fibrin was formed. It would seem that this question of the presence or absence of nucleo-proteids in the red corpuscles is an important one in explaining some of the differences that exist in coagulation and fibrin formation in the mammals on the one side and the birds and amphibia on the other.

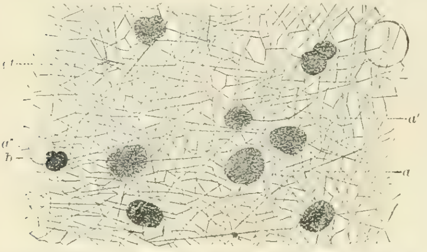

FIG. 537. Fibrin Network from the Blood of the Frog. *a*, *a′*, *a″*, Granular mass of fibrin; *gf*, isolated granules of fibrin; *b*, deformed leucocyte. (After Renaut.)

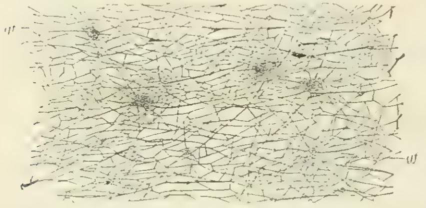

FIG. 538.—Fibrin Network from the Blood of Man. *gf*, *gf*, Nodal points formed by grains of fibrin. (After Renaut.)

Fibrin is insoluble in water, alcohol, and ether. It expands in 0.1 per cent. hydrochloric acid, also in 0.1 per cent. caustic potash or soda, to a gelatinous mass, which after several days will dissolve at the ordinary temperature; it will dissolve more readily but still slowly at body temperature. Fibrin is also slowly soluble in five to ten per-cent. solutions of certain salts, such as sodium chloride, sodium sulphate, potassium nitrate, magnesium sulphate, ammonium sulphate, also in iodides and in solutions of urea. It is said that the fibrin obtained from venous blood is slightly more soluble in salt solutions than that obtained from arterial blood.

Blood yields from 0.2 to 0.4 per cent. of its weight of dry fibrin (Schäfer).

For the elementary composition of fibrin, Hammarsten gives the following:

C	52.68
H	6.83
N	16.91
S	1.10
O	22.48

The way in which fibrin is formed and certain other phenomena will be discussed under *Coagulation*.

PLASMA AND SERUM.—It is convenient to describe these two components of the blood together, for, with the exception of certain proteids or fibrin factors present in the plasma, the remaining constituents are identical with those in serum. The relationship of the different parts of the blood to each other may be conveniently shown as follows:

Living blood = plasma + corpuscles.
Dead blood = clot + serum.
clot = corpuscles + fibrin.
serum = plasma − fibrin(ogen).
plasma = serum + fibrin(ogen).

Plasma contains about ten per cent. of solids, the red corpuscles about forty per cent.

Plasma may be separated from the corpuscles in various ways. A common method is to collect the blood in a receptacle surrounded by ice. Cold retards coagulation so that the corpuscles may have time to settle at the bottom of the jar, leaving the clear plasma entirely separated. Another method is by the use of the hæmatocrit, centrifugalizing, etc.; the corpuscles accumulate in an almost solid mass and the volume can be read directly. The average percentage of corpuscles in human blood, as obtained by various methods, is 48 per cent. for males, very nearly one-half of the entire amount of blood; in females it is 43.3 per cent., and in children from six to thirteen years it is about 45 per cent.

Salted Plasma.—Coagulation may be delayed by the addition of certain substances to the blood, among which are neutral salts. If the blood flowing from a cut artery is allowed to mix with an equal volume of a saturated solution of sodium sulphate, or with a ten-per-cent. solu-

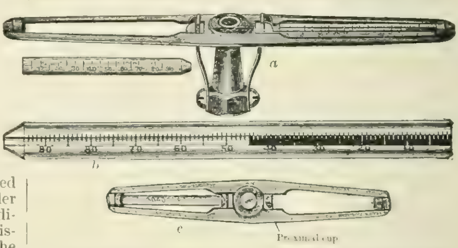

FIG. 539.—Daland's Hæmatocrit. *a*, Tubes have lens fronts magnifying the column of blood. (About half actual size.) *b*, Percentage tube. (Nearly twice actual size.) *c*, Top view of hæmatocrit. (One third actual size.)

tion of sodium chloride, or with one-third of its bulk of a saturated solution of magnesium sulphate, coagulation will be prevented and the corpuscles will subside, leaving the plasma diluted with the salt solution (salted plasma) clear. If, however, the above solutions are diluted with a sufficient amount of water, coagulation will usually occur.

Oxalate plasma is obtained by the addition of potassium or sodium oxalate to the blood; these salts combine with the calcium of the blood forming the insoluble calcium oxalate. The corpuscles and plasma separate as previously described and coagulation is prevented. If, however, more calcium be added to the mixture, coagulation occurs. The importance of the presence of calcium salts in the process of coagulation will be referred to later on.

Gases.—The gases present in the plasma have not been altogether satisfactorily investigated. They are probably not very different from those in the serum. According to Bunge, in the dog they consist of from 43 to 57 volumes of carbonic anhydride, 2.25 of nitrogen, and 0.25 of oxygen. The oxygen and nitrogen are probably simply in solution in the plasma, the carbonic anhydride for the most part being in chemical combination with sodium as the carbonate and bicarbonate. The alkaline phosphates also exist in combination. In the corpuscles, where they are present in considerable quantity, they may play an important part in fixing the CO_2.

Chemical Analysis of Plasma.—The average of three analyses of the plasma from the horse, made by Hammarsten, is given below, 1,000 parts having been used. An analysis by Hoppe-Seyler, also of the horse, is given for comparison.

	Hoppe-Seyler.	Hammarsten.
Water	908.4	917.6
Solids	91.6	82.4
Total proteids	77.6	69.5
Fibrin	10.1	6.5
Globulin	....	38.4
Serum albumin	....	24.6
Fat	1.2	
Extractive substances	4.0	12.9
Soluble salts	6.4	
Insoluble salts	1.7	

Inorganic Substances in Plasma.—Plasma consists of about ninety per cent. of water, the inorganic salts occurring to the extent of about 0.8 per cent. The principal salt is the chloride of sodium. Carbonate of sodium is probably the next most abundant salt, and it is to this salt chiefly that the plasma owes its alkalinity and its power of absorbing carbonic acid. In addition to these, small amounts of the following salts appear to be present: chloride of potassium, sulphate of potassium, phosphate of calcium, phosphate of sodium, and phosphate of magnesium, and probably chloride of calcium.

Organic Constituents.—For convenience these may be divided into proteids (serum albumin, etc.) and non-proteids, and the latter again divided into nitrogenous (kreatin, etc.) and non-nitrogenous (dextrose, etc.).

Proteids.—The proteids of plasma are: one or more closely allied albumins (serum albumins); two globulins, namely, serum globulin and fibrinogen; a nucleo-proteid or nucleo-proteids. Blood normally contains neither albumose nor peptones. The *albumins* of plasma are also found in the serum after the blood has coagulated, and from this fact they have doubtless received the name of serum albumins. According to its susceptibility to heat coagulation, Halliburton has shown that there are in reality three kinds of albumin: α-albumin coagulating at 72 to 75° C.; β-albumin at 77 to 78° C.; and γ-albumin at 83 to 86° C. In the plasma of horse, ox, and sheep blood, the α-albumin is absent, the other two are present; in man and all other mammals and birds investigated by Halliburton, all three were found present. In the reptiles, amphibia, and fishes examined only the α-albumin was found.

The *globulins* of plasma consist of serum globulin and fibrinogen. Serum globulin (paraglobulin, Kühne; fibrino-plastic substance, A Schmidt) coagulates at a temperature of 75° C. This degree of coagulation is almost constant for the animals examined. According to Hammarsten the percentage of the globulins in the plasma of man is 3.10 per cent.; in the horse 4.56 per cent.; in the ox 4.17 per cent.

The *fibrinogen* is the substance which is responsible for the so-called spontaneous coagulability of the plasma. It is precipitated from plasma along with serum globulin by saturation with magnesium sulphate or sodium chloride. This precipitate forms the plasmine of Denis, and on being dissolved in a more dilute solution of salt causes coagulation. As a result of numerous researches, it seems likely that fibrinogen is not a simple substance, but is probably either a mixture or a loose combination of three substances: (1) fibrinogen proper, coagulating at 56° C; (2) fibrino-globulin (Hammarsten), coagulating at 65° C.; (3) a nucleo-proteid.

Mathews,* in a recent article on the origin of fibrinogen, concurs with Hoffmeister in the view that leucocytes are concerned in proteid digestion, basing the evidence chiefly on the fact that the blood proteids remain practically constant, even during fasting. Under the latter condition the proteid material is derived from the wasting tissues and the leucocytes are considered as carriers of the proteid to the blood, in a way analogous to that seen in the phagocytes during the removal and assimilation of the wasting tissues of the tadpole's tail, etc.

His experiments also confirm those of Bizzozero and Dastre, that by successive bleedings, defibrinations, and reinjections the fibrinogen may be completely removed from the blood of dogs and cats. The lack of fibrinogen appeared to cause no serious or characteristic symptoms. After the withdrawal of the fibrinogen, in the manner above described, it redeveloped in the body with considerable rapidity, reaching its normal amount in two or three days; it sometimes developed to more than the normal amount. The redevelopment of the fibrinogen took place normally in the absence of the spleen, pancreas, kidneys, and reproductive organs. Experiments also showed that the muscles apparently had no influence upon the production of fibrinogen. On the other hand, the fibrinogen is not redeveloped (or at a greatly reduced rate) if the small and large intestines be removed. The conclusion is that the intestinal area more than any other part of the body is concerned in the formation of fibrinogen. The blood of the mesenteric vein is constantly richer in fibrinogen than arterial blood, while other venous blood is poorer in fibrinogen than arterial. Beyond the fact that *nucleo-proteid* is present in the plasma and that it seems to be an important factor in the development of fibrin, very little is known of it. It is supposed to be confined to the leucocytes and platelets, and possibly there is a trace of it in the red corpuscles (mammals), which escapes when the blood is shed. The principal reasons for this belief are that there is known to be a considerable amount of nucleo-proteid in leucocytes and similar cells (lymph, thymus, etc.). In plasma where the corpuscles have been precipitated, more nucleo-proteid is obtained from the lower layers of the plasma where the leucocytes are most abundant, and least from the upper layers where the leucocytes are scarce. Again, the pericardial, hydrocele, and ascitic fluids frequently contain no leucocytes. When this is the case no nucleo-proteid is present, and there is no coagulation although the fluids contain fibrinogen.

Nitrogenous Substances Not Proteids.—The most important of these are urea (0.02 to 0.05 per cent.), kreatin, kreatinin, and uric acid. According to Gréhant and Quinquand, the quantity of urea in the blood taken from the splenic, portal, and hepatic veins is slightly greater than that taken from the carotid artery. Lecithin is also said to occur in plasma. Jecorin is said to be a constant constituent of the plasma. It is a substance which reduces Fehling's solution and is soluble in ether, but is not fermentable. It occurs in greater quantity in venous blood than in arterial blood.

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* American Journal of Physiology, vol. iii., 1899.

The Non-Nitrogenous Substances.—These consist of the carbohydrates and fats. In addition there are present small quantities of cholesterin and a lipochrome, and perhaps of sarcolactic acid.

Carbohydrates.—These consist of dextrose or grape sugar, glycogen, and an animal gum.

The *dextrose* is always present in the plasma, even in starving animals. In man it is present normally to the extent of 1.2 parts per 1,000 and in the dog from 1.1 to 1.5 parts per 1,000. It seems to be present in nearly equal amounts in all parts of the blood except that of the portal vein, where it is markedly increased during the digestion of carbohydrate food. Between the periods of digestion, Bernard found more sugar in the hepatic veins than in the portal vein or in the general circulation. Pavy and some others have not found this difference, while others have confirmed Bernard's observations. Bernard and others have also found a larger amount of sugar in arterial than in venous blood. Pavy as a result of eleven experiments finds that this difference is very slight, the sugar in the arterial blood exceeding that of the venous by only 0.003 part per 1,000. He concludes that these differences have not been constant and are so slight that they may come within the range of experimental error, and that no appreciable difference exists between the two.

The amount of sugar in the blood is increased as the result of a hemorrhage, due perhaps to an increase of lymph, which contains a larger amount of sugar than blood does; or as an effect of an injury acting through the nervous system to stimulate the production of sugar from the liver glycogen. If the amount of sugar in the blood be increased artificially or otherwise to more than 2.5 or 3 parts per 1,000, the excess passes off in the urine. The quantity is increased in diabetes, whether this be a result of disease or of puncture of the floor of the fourth ventricle.

A very slight amount of *glycogen* may be obtained from fresh blood. It is said that traces of it occur in the plasma. These are undoubtedly derived from disintegrated leucocytes, which, as is well known, contain it. Kaufmann has pointed out that the quantity of glycogen is increased in the blood upon the removal of the pancreas (from 0.025 to 0.59 per litre).

Freund has obtained from the blood a carbohydrate resembling that described by Landwehr under the name of *animal gum.* It has a formula of $(C_6H_{10}O_5)_n$ and is converted by boiling with dilute mineral acids into a substance which reduces Fehling's solution, but is not fermentable nor rotatory for polarized light.

Fats.—These are present in the plasma in but small and variable quantity (from 0.2 to 1 per cent.), and are most abundant after a meal in which much fat has been eaten. The plasma or serum may then have a milky appearance on account of the admixture with fat-containing chyle. A small amount may exist in the form of soap. The fatty acids also appear to be partly in combination with cholesterin. Hoppe-Seyler states that the cholesterin in the plasma or serum amounts to about 0.05 gm. per 100 c.c. of blood.

The *serum* is a viscid liquid which is more alkaline than the plasma (Hammarsten). Its specific gravity in man ranges from 1.027 to 1.032, averaging about 1.028. Blood serum is in man a pale yellow color, in the horse an amber yellow. It is ordinarily clear, but after a meal may be opalescent on account of the contained fat. The yellow coloring matter of serum is a *lipochrome* or fat-coloring matter which is soluble in amyl and ethyl alcohol. In the serum from the horse it is said that biliary coloring matters (bilirubin) and others often occur. Lipochrome belongs to the so-called group of lutens.

Lactic acid or sarcolactic acid is said to be a constant constituent of the normal plasma. Salomon found it only in blood from the dead body, but others have affirmed its existence in fresh blood (dog), and that it also exists to some extent in the corpuscles. It is increased in amount by the intravenous injection of dextrose, and appears to combine with sodium hydrate, driving out CO_2.

Ferments.—Besides the fibrin ferment (thrombin) or its precursor (prothrombin), which will be discussed under *Coagulation,* the blood is said to contain a diastatic ferment converting starch and glycogen into maltose, and a cleavage enzyme, *glucase* or *maltase,* which converts maltose into dextrose; a glycolytic ferment producing the disappearance of sugar, and a fat-splitting ferment (lipase).

Diastatic Action.—The conversion of starch into dextrin and maltose and ultimately into dextrose has been effected from the blood and lymph. This result has been obtained by mixing blood or serum with a glycogen or starch mixture and keeping it at body temperature. Cavazzani has obtained the most marked action with blood taken from the portal vein.

Glycolytic Action.—Bernard has shown that the quantity of sugar in the blood diminishes on standing. This is also true of the lymph. Arthus thinks it probable that the ferment is formed from the leucocytes during coagulation. A temperature above 54° C. destroys all action. Lépine and Barral, as well as Arthus, have shown that the glycolytic action takes place in the complete absence of micro-organisms. Kraus finds that the glycolysis occurring in blood on standing is accompanied by a splitting off of CO_2, which is probably due to oxidation.

Fat-Splitting (*Lipolytic*) *Action.*—Hanriot has observed that the serum possesses the property of splitting neutral fats. Cohnstein and Michaelis have observed another action, not to be confounded with the above, which consists in transforming chyle fat, in the presence of oxygen, into an unknown substance soluble in water.

The Globulicidal Action of Serum.—Although this phenomenon is treated of largely in pathological literature, it seems proper to give it a brief notice here. Landois was the first to show that when the serum from one animal, in some cases at least, was injected into another animal of different species, it destroyed the red corpuscles, setting free their hæmoglobin and thus producing laky blood. After a fuller investigation of this fact, the phenomenon has become known under the term of "globulicidal" action of serum. It has been found that different kinds of serum show different degrees of globulicidal activity, and that white corpuscles may be destroyed as well as the red ones. The serum from man or the dog is strongly globulicidal to the blood of the rabbit. The matter is complicated by the fact that the serum of some animals does not produce any harmful result, as, for example, that of the horse, which does not appear to have any globulicidal reaction on the blood of the rabbit. That this phenomenon is not due primarily to differences in density, osmosis, variations in salts, etc., is shown by the fact that when the serum to be injected is subjected to a temperature of 55° to 60° C. for a few minutes the globulicidal action is destroyed and laky blood does not result. The above temperature is not high enough to cause coagulation of any of the proteids in the serum, and there is no visible change in the appearance of the liquid.

Maragliano and Castellino have noted that the globulicidal power is greater in unhealthy than in healthy persons. Charrin and Roger, also Daremberg, have shown that the serum of the dog will destroy the corpuscles of the guinea-pig in two or three minutes and of the pigeon in twenty-five or thirty minutes.

Bactericidal Action of Serum.—The serum of certain animals has been shown to exercise a destructive action upon some kinds of bacteria as well as upon the blood corpuscles. Much, however, remains to be investigated. That this property of the serum assists in the explanation of the immunity of some animals to certain diseases seems likely. The dog, goat, and some others seem to be normally immune to tuberculosis. Other analogous examples are numerous, and the serum of such supposedly immune animals is used, on account of its bactericidal action, to alleviate or cure other persons or animals suffering from a disease, to which the animal from which the serum was obtained is immune. This property is, therefore, of much importance in serum-therapy. Faggioli has observed that serum is quite generally destructive to protozoans, while Chenot and Picq have noted the bactericidal action of bovine serum upon the virus of glanders.

Transfusion of Blood.—The process of transferring living blood from one person to another or from a lower animal to man was at one time regarded as very valuable, as being of use in replacing blood that had been lost by hemorrhage and for the cure of various diseases. Fatal as well as successful results followed the operation, but from what has been learned later regarding the globulicidal action of serum, and the fact that the transfused blood, whether introduced directly or after defibrination, is liable to contain a quantity of fibrin ferment sufficient to cause intravascular clotting, the method has been regarded as too dangerous to practise. The injection of physiological salt solution (0.65 per cent. sodium chloride) has been found to be an efficient substitute. It is isotonic to the corpuscles and increases the bulk of the circulating blood.

The subject of the *coagulation or clotting of blood* is treated in a separate article entitled *Coagulation*.

GENERAL VARIATIONS IN THE BLOOD.—As a résumé of the general differences existing between arterial and venous blood, the following table is appended:

ARTERIAL BLOOD.	VENOUS BLOOD.
Color.—Bright red, monochroic; oxyhaemoglobin.	Purple, dichroic; reduced hæmoglobin.
Specific Gravity. Less.	More.
Number of Corpuscles.—Relatively less; blood more diluted.	Relatively more; blood more concentrated.
Temperature.—Slightly warmer in general.	Slightly cooler, but exceptions; warmest blood in the body found in the hepatic vein.
Coagulation. More coagulable.	Less coagulable.
Fibrinogen. More.	Less, except in mesenteric vein.
General Composition.—More uniform.	Numerous local variations.
Gas.—More O, less CO_2.	More CO_2; less O, except pulmonary veins.
Water. More.	Less; transudation of water through the capillaries causes venous blood to be more concentrated.
Urea and Extractives.—Less.	More; except renal vein.
Glucose.—Mote.	Less.
Fat. Less.	More.
Fibrin. More.	Less.
Serum Albumin.—Less.	More.
Salts.—More.	Less.

Local Variations of Blood.—Certain organs cause the blood which passes through them to undergo more or less of a modification in respect to its general properties and composition.

The Blood of the Capillaries.—Virchow has noted that the blood from the capillaries does not coagulate after death even when exposed to the air, which apparently indicates some modification of the fibrin or fibrin ferment.

The Blood of the Mesenteric Vein.—More fibrinogen is found in this vein than in arterial blood.

The Blood of the Portal and Hepatic Veins.—Drosdoff has observed in dogs fed with meat, bread, and milk that the portal vein contains fewer corpuscles and more plasma than that of the hepatic. There is also more fatty material present in the portal, which may apparently be stored up in the liver. During digestion the portal vein contains more sugar than the hepatic, but later the reverse is the case, although it is not likely that the portal vein is at any time entirely destitute of it.

The Blood of the Splenic Vein.—The evidence is conflicting here. Some have claimed that a larger number of corpuscles are present in this blood, while others hold that they are fewer and are destroyed in the spleen as well as in the liver.

The Blood of the Renal Vessels.—The differences are best shown in the following table.

	Renal artery.	Renal vein.
Water	790	778
Solids	210	222
	1,000	1,000
Albuminoids	less.	more.
Mineral salts	more.	less.
Urea	"	"
Uric acid and kreatin	"	"
Oxygen	"	"
Carbon dioxide	"	"

Very briefly, there is loss of water, salts, urea, CO_2, and extractive materials.

The Blood of the Glands.—The blood which leaves a resting gland is dark and possesses the ordinary characters of venous blood; that leaving an active gland is brighter (Bernard) and contains less CO_2 than common venous blood, because a certain amount of the CO_2 is given off in the fluid secreted by the glands, especially the salivary.

The Blood of the Placenta.—This appears to contain more corpuscles and less water than the venous blood of the arms, for example. More urea is also present, but further investigation is necessary.

Menstrual Blood.—Menstrual blood seems to be deficient in the fibrin-forming elements. The blood does not coagulate or only slightly under normal conditions. As this is a capillary hemorrhage and such blood does not coagulate readily, we have a reasonable explanation for this insufficient coagulation phenomenon. Furthermore, the blood becomes mixed with the vaginal mucus and has a tendency toward acidity.

The Blood in Hibernating Animals.—Vierordt has shown that the blood in such animals may show a diminution in the red corpuscles from a total of seven million to two million per cubic millimetre; the changes in the blood with respect to the hæmoglobin being very feeble, and but a slight difference existing in general between the arterial and venous blood.

LITERATURE.—The literature upon the blood and its constituents is so extensive that no attempt will be made to give a detailed list of such articles. Among those which the writer has frequently consulted should be mentioned books, monographs, and papers by Schäfer, Woodridge, Norris, Mathews, Stewart, Howell, Hammarsten, Gamgee, Viault et Jolyet, Maurel, Waller, and numerous others.

Pierre A. Fish.

BLOOD. (PATHOLOGICAL.)—APPARATUS AND TECHNIQUE EMPLOYED IN THE CLINICAL EXAMINATION OF THE BLOOD, AND THE INFORMATION OBTAINED THEREFROM.

PRÉCIS.

I. *Fresh-Blood Specimen.*
  1. Apparatus and technique employed in taking fresh specimen of blood.
  2. Information obtained by the examination of fresh specimen of blood.

II. *Blood-Corpuscle Counting.*
  1. History of development of instruments for enumeration of blood corpuscles.
  2. Apparatus and technique employed in blood-corpuscle counting.
  3. Information obtained from blood-corpuscle counting.

III. *Hæmoglobin Estimation.*
  1. Apparatus and technique employed in estimating hæmoglobin.
  2. Information obtained from estimation of hæmoglobin.
  3. Color index.

IV. *Blood-Clotting.*
  1. Apparatus and technique employed in measuring "coagulation time" of blood.
  2. Information obtained by measuring "coagulation time" of blood.

V. *Detection of Blood Stains.*

[*Note.*—As this article deals with such simple apparatus only as may be employed at the bedside, the reader is referred for full information upon the more complicated tests and apparatus for detecting blood stains to the article *Blood Stains.*]

VI. *Dried Specimen of Blood.*
  1. Apparatus and technique employed in taking dried specimen of blood.
  2. Apparatus and technique employed in fixing dried specimen of blood.
  3. The dyes employed for staining the blood.
  4. The technique employed in staining the blood.
  5. Formulæ of blood stains.
  6. Table of all blood cells and their staining peculiarities.

VII. *Table Showing All the Information Obtained by the Use of the Instruments Described in this Article.*

VIII. *A Chart for Making Full Report upon the Blood.*

[Note.—The tables which conclude this article are not intended to be complete explanations of the diseases therein mentioned. They are, however, accurate for reference for all blood changes in those diseases. For full instruction upon the following not included in this article the reader is referred to other articles in this Handbook, such as those on *Anæmia, Leucocytosis, Blood Stains* (*Medico-Legal Consideration*), *Histological Technique, Malaria, Typhoid Fever,* etc.]

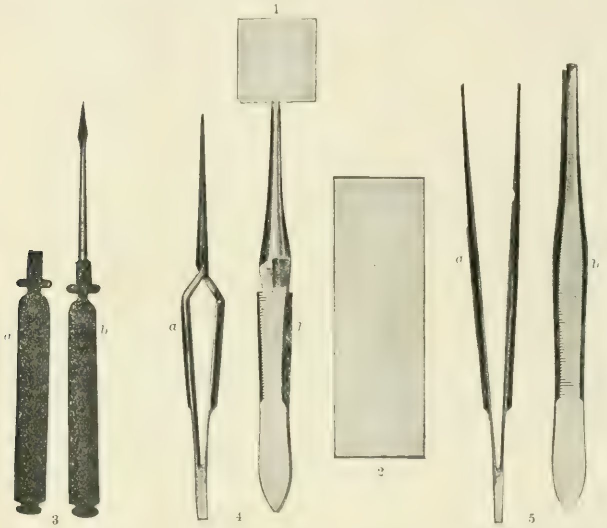

Fig. 540.—1, Bausch and Lomb, $\frac{7}{8}$ inch, No. 1 cover slip; 2, Bausch and Lomb, extra thin slide; 3, blood sticker, two views—*a*, point in sheath for carrying instrument in pocket; *b*, point in place ready for use; 4, clamp forceps, two views—side view, showing close apposition of tip of limbs; front view, showing proper extent of grasp of cover slip (1); 5, open forceps, two views—side view, front view. (Note: Instruments made by F. Arnold & Son, instrument makers, Baltimore, Md.

I. Fresh-Blood Specimen.

In preparing the blood for microscopic examination, however so careful the technique employed, the operator is subjecting one of the most delicate tissues of the body to very rough and unnatural surroundings. When one realizes the exquisite smoothness of the intima of the blood-vessels, the wonderfully regulated temperature of the body, the delicate structure of the red cell, the even more delicate structure of the plate which without most careful preservation is entirely destroyed a few seconds after exposure to the air—when one realizes all these factors against observation of the blood as it appears in the circulation, it is a surprise that any technique is delicate enough. This realization at the same time emphasizes the importance of observing every precaution which experience has shown to be necessary in the preparation of the blood specimen which shall be, outside of the body, as nearly as possible representative of the blood as it appears in the circulation.

The object then of apparatus and technique is to produce surroundings as nearly like those normal to the blood in circulation as possible. To accomplish this we must observe the following: (1) Absolute cleanliness and freedom from moisture; (2) avoid chilling the blood; (3) avoid exposure to air; (4) avoid rough treatment of the drops and consequently of the constituents thereof—the corpuscles.

The Cover Slip.—Absolute Cleanliness. The cover slip should be the thinnest made and square in shape (Bausch and Lomb, No. 1, $\frac{7}{8}$ in. (see Fig. 540, 1). The thicker cover slips are often too thick for the focus of the one-twelfth immersion lens, and not infrequently specimens from interesting cases at a distance from the laboratory and received by mail cannot be examined accurately owing to this annoying condition. It is a good rule for those engaged in blood work not to have the thicker cover slips under any circumstance.

The Slide.—For the same reason the *thin* slide should be employed (see Fig. 540, 2). Two jars, one containing thick slides for urine work, and thin for blood work, will be found a convenient arrangement. These cover slips and slides should be kept in fifty per cent. alcohol. When to be used they should be rubbed with a bit of clean silk, or some fabric free from lint specks. They should be rubbed quite free of any cloudiness or dust and then dried. This last can be done either by pouring a little ether over the glass and rubbing again or by heating gently over a flame. The cleaned slip and slide should now be laid upon a sheet of clean paper. The following instruments, as first recommended by W. S. Thayer of the Johns Hopkins University, will be found essential:

The clamp forceps are so made that the extreme tips of the limbs meet before any other portion, and this enables one to take a small but firm grasp of the cover slip (see Fig. 540, 4, *b*). The clamp, moreover, enables the operator to give his whole attention to following the technique, as given below, without being diverted by keeping a grasp on the cover slips. By placing the cover slip in the clamp forceps it can be kept free from dust and moisture from the fingers and will be ready for use.

The lobe of the ear is by far the best locality for puncture. For the following reasons: (1) Less sensitive; (2) the act of puncture and the blood are not seen by the patient, important with nervous people and children; (3) pressure, if necessary, is more readily exerted and produces better results; (4) the skin in this locality is softer and cleaner; (5) there is less likelihood of subsequent infection.

The lobe of the ear is then gently wiped (not rubbed, as this produces hyperæmia) with a silk rag moistened in alcohol and the skin is then dried with ether. If ether is not to be had, it is better either to dilute the alcohol three or four times or to use distilled water. Alcohol if left on the skin hardens the blood and so injures the specimen.

The Sticker.—The sticker is now employed (see Fig. 540, 3). This is extremely sharp and is diamond shaped on cross section; the object being to produce a similarly shaped wound, and therefore one which will the more readily bleed. A surgical needle may be used, but an ordinary needle or pin is very unsatisfactory. If, however, one or the other of the latter is all that can be obtained, it should be boiled. When cleanliness is observed, it is only necessary to dip the end of the sticker into alcohol before and after making the puncture.

The most dependent portion of the lobe of the ear is now punctured by a stabbing motion, the sticker being held as in illustration (Fig. 541). The first drop is wiped away, the second allowed to flow, if possible, without pressure being made upon the skin. If pressure be necessary it should be exerted far away from point of puncture, so that this artificial means shall not alter the character of the drop taken for examination.

Avoid Chilling the Blood. It must be remembered that the blood is being submitted to a lower temperature than normal in this proceeding, and in order to *avoid chilling the blood* it is a good plan to warm the slide and cover slip over a spirit lamp, or to have another person briskly rub the slide with a bit of silk

The clamp forceps holding the cover slip (see Fig. 540, 4) are now brought toward the ear, and the under surface of the cover slip—and therefore that free from dust—is made to touch the *apex of the drop* of blood, *not the skin of the ear* (Fig. 542). The cover slip is at once carried to the warmed slide and gently lowered.

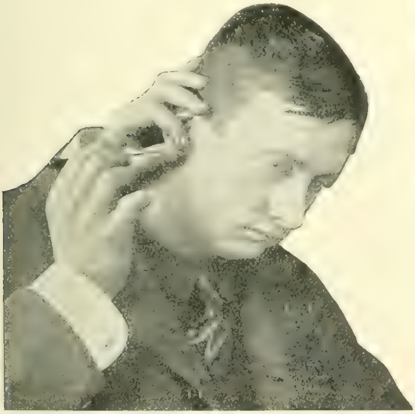

FIG. 541.—Method of Making Puncture for Fresh and Dried Specimens of Blood. Shows position of hands and wrist just as puncture is about to be made

Avoid Rough Treatment. The cover slip should not be dropped on the slide. One side of the cover slip should be rested on the slide and gently lowered until the limb of the forceps touches the slide. The forceps are then opened and by a quick jerk drawn away (see Fig. 543).

Avoid Exposure to Air. It must be remembered also that the air is a destructive medium to the blood, and the time occupied for these steps must be as brief as possible.

The cover settles and the good blood specimen spreads *equally in all directions*, being for the most part circular with fine spicules at the periphery of the circle. The drop should not be so large as to reach the margin of the cover slip when on the slide.

This technique may be summarized as follows:

1. Apparatus. Thin slide, square thin cover slip, sticker and clamp forceps. Alcohol, ether, spirit lamp, silk cloth.
2. Absolutely clean point of puncture and apparatus.

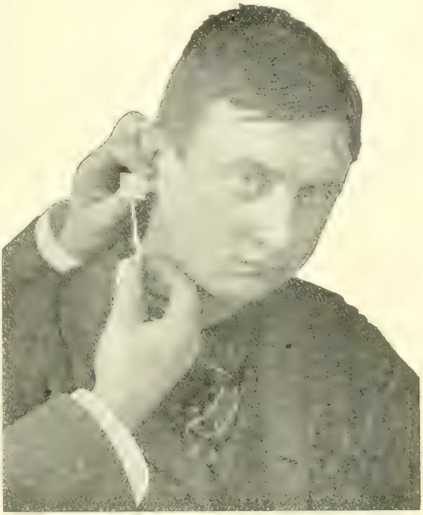

FIG. 542.—Method of Taking Drop of Blood for Fresh and Dried Specimens of Blood. Shows how to hold forceps and ear, how to steady hands, and the extent of grasp of cover slip by clamp forceps.

3. Seize cover slip in clamp forceps and place near at hand.
4. Light puncture of the most dependent portion of lobe of ear.
5. Warm slide and cover slip gently over spirit lamp; or have another person rub slide briskly with silk cloth.
6. Wipe away drop from point of puncture. (If pressure is required, exert it far away from point of puncture.)
7. Touch apex of drop with under surface and centre of cover slip
8. Place cover slip promptly but gently on slide.

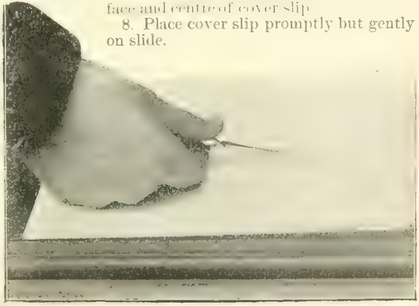

FIG. 543.—Correct Position of Hand in Holding Clamp Forceps. Cover slip resting on slide. The illustration represents the position just before the forceps are opened and jerked away.

Characteristics of a Good Fresh-Blood Specimen.—Gross: 1. Blood does not reach margin of cover slip. 2. Is of a circular shape with fine spiculated appearance at periphery. 3. Is thinner in the centre than at margin of specimen. (See Plate XIII., Fig. 1.)

Microscopic: 1. Corpuscles each lying separate with some little space between—not in rouleaux. 2. Majority of corpuscles stationary. 3. Each corpuscle circular—*not crenated.* (See Plate XIII., Fig. 6.)

Poikilocytosis is of course pathologic and cannot be avoided; crenation is not, however, and is usually due to faulty technique. (See Plate XIII., Figs. 3 and 5.)

Characteristics of a Poor Fresh-Blood Specimen, and Such as Condemn It for Examination.—Gross: 1. Blood thick and oozing out from under cover slip indicates that too much blood has been taken. 2. Irregular shape indicates either that too much blood has been taken, or that dust has been on the slip or slide, or that the blood has been chilled. 3. Thick at one point and partially spread at another indicates dust or moisture. 4. Lump of blood—no spreading—indicates general uncleanliness.

Microscopic: 1. Structureless masses. 2. Abundance of rouleaux. 3. Much crenation. 4. Corpuscles closely placed, giving tiled-floor appearance. 5. Corpuscles rapidly floating about specimen. 6. Corpuscles ragged and mutilated. 7. White corpuscles broken into granular collections. (See Plate XIII., Figs. 3 and 5).

What can be Learned from Fresh Specimens of Blood.—When the precautions laid down in the foregoing have been observed, the following objects may be distinguished:

1. The Red Blood Corpuscles—non-nucleated in the normal.

Size—7*μ*. (Note: μ = micron = $\frac{1}{25400}$ of an inch. It is well to become familiar with the size of the red cell, and to use it as a unit of measurement when speaking of other bodies, as twice, thrice, etc., the size of the red cell.)

Shape—biconcave discs.
Color—pale yellow.
Character—elastic.

Tend to form rouleaux. Become crenated. May contain bright round spots termed "artifacts."	Conditions due to faulty technique.

The adjective artifactitious, or simply factitious, might be applied to the last three conditions, as they are the result of manipulation

2. Microcytes or Macrocytes. 3. Poikilocytes. 4. Nucleated Red Cells. { Normoblasts. Gigantoblasts. 5. Lake-like Areas with irregular shape and margin in the red cells, due to deficiency of hæmoglobin, termed by Maragliano "degeneration areas," called also vacuoles.	In anæmia.

6. Shadow Corpuscles, described first by Norris, are seen in the blood of anæmia from toxic agents and burns. These are red cells deprived of hæmoglobin. They can be artificially produced by adding water to the blood specimen.

The White Blood Corpuscles—Nucleated Cells.
7. Small Mononuclear or Small Lymphocytes.
8. Large Mononuclear or Large Lymphocytes.
9. Transitional Mononuclear or Transitional Lymphocytes.
10. Polynuclear Leucocytes.
11. Eosinophiles.
12. Myelocytes in leukæmia. (The Mastcells cannot be detected in the fresh specimen.)

An approximate idea of an increase in the white cells as a whole, and one or other variety of these individually, can be had from the fresh specimen. More than four or five white cells in a *well-spread* field with a one-twelfth immersion lens may be taken to indicate a leucocytosis. In lymphatic leukæmia the increase in the small mononuclear leucocytes is readily appreciated; so also the presence of the cells normally found in the bone marrow, as the myelocytes, can be detected in the fresh specimen in cases of spleno-medullary leukæmia. In inflammatory leucocytosis the increase in the polynuclear leucocytes can be noted. The increase in the eosinophiles, so important a diagnostic sign in trichinosis, etc., can also be detected.

13. The Plate[*] and the Plaque—non-nucleated.
Size—One-seventh the size of the red cell (1 *μ*).
Shape—irregular.
Color—colorless.
Not visible normally.

By placing a drop of Hayem's or Pacini's solution[†] over the point of puncture (the finger must be used for this purpose) and allowing the blood to mingle with this preservative fluid the plates may be seen. The cover slip is applied to the drop in the same way as when taking a fresh specimen.

We have no systematic work upon the significance of the presence of these bodies.

The writer has noted them in great numbers (without the use of a preservative fluid) in the blood of pneumonia cases, in a case of grave anæmia secondary to malaria, and in a case of Hodgkin's disease.

The work of Osler, Bizzozero, Schimmelbusch, Welch, and Eberth has been more to prove that these bodies are separate corpuscular elements than to explain their association with disease. An exception to this statement should be made in favor of Welch's work, which goes to show that these bodies are the active agents in the formation of the white thrombus; but even this has not, as yet, been of any clinical value.

14. Fibrin does not, normally, appear for some time in a well-taken fresh specimen. Its presence shortly after taking the specimen is therefore of pathological significance. We have not been able as yet, however, to attach any diagnostic value to this condition.

15. Blood Dust (hæmokoniosis, literally, blood full of dust, of Müller) can be seen as floating particles about one-twentieth or one-thirtieth the size of the red cell. No satisfactory explanation of the significance of these particles has as yet been given.

16. The Tertian and Quartan Malarial Parasite in all its stages of development, and many of the stages of the Æstivo-autumnal Malarial Parasite, may be seen with the one-twelfth oil-immersion lens.

17. The Filaria Sanguinis Hominis may be seen with the 7 or 9 Leitz lens.

18. Spirochaëte of Relapsing Fever may be seen with the 7 or 9 Leitz lens.

All this information is to be had by the simple procedure of taking, in the way described, a specimen of blood. All these points will be found grouped in the table at the end of this article.

Having ascertained, then, from the fresh specimen that there is a decrease in the number of red cells, or an increase in the number of white cells, it becomes necessary to determine this decrease and increase definitely, for which purpose additional instruments are required.

II. Blood-Corpuscle Counting.

History.—It is only of late years that the methods of enumerating the blood corpuscles have been simplified so as to be clinically applicable, the complicated apparatus heretofore used having had place in works on physiology only. It is therefore of value to trace the development of our present simple apparatus from its complicated beginnings. When we look over all the methods employed to accomplish this last, we find that investigators have endeavored to construct apparatus along three separate lines, as follows: 1. Actual enumeration. 2. Centrifugalizing and estimating cells according to amount of sediment. 3. Color changes and opacity due to decrease in number of cells.

This will therefore be, not a history of blood counting in chronological order, but rather the record of the development of apparatus along these three lines.

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[*] The term plate is here used to refer to the corpuscles; plaque to the aggregation of these plates. Platelet, a term synonymous with plate, is best discarded.

[†] *Hayem's Solution.*

Bichloride of mercury	0.5
Sodium sulphate	5.
Sodium chloride	1.
Distilled water	200.

Pacini's Solution.

Bichloride of mercury	2.
Sodium chloride	4.
Glycerin	26.
Distilled water	226.

EXPLANATION OF
PLATE XIII.

EXPLANATION OF PLATE XIII.

(DRAWN BY DR. E. DUNNING.)

FIG. 1.—Gross appearance of well-taken fresh-blood specimen.	See p. 39: *Characteristics of a Good Fresh-Blood Specimen*
FIG. 6.—Microscopic appearance of well-taken fresh-blood specimen.	
FIG. 3.—Microscopic appearance of poorly taken fresh-blood specimen.	See p. 40: *Characteristics of a Poor Fresh-Blood Specimen.*
FIG. 5.—Microscopic appearance of poorly taken fresh-blood specimen.	
FIG. 2.—Microscopic appearance of **the Thoma-Zeiss** counting stage with normal blood diluted with Toison solution. Red cells unstained; white cells stained blue. This is with the low-power objective (3 Leitz) which takes in all sixteen squares (see Fig. 555, p. 44), but does not magnify the cell as much as the higher power (see Plate XIII., Fig. 4), and which therefore greatly increases the task of counting.	See p. 45.
FIG. 4.—Same as Fig. 2, Plate XIII., except that the blood is that of leukæmia (120,000 leucocytes to the cubic millimetre), and the objective is of high power (7 or 9 Leitz). This takes in only one-sixteenth of the entire field, but it renders the corpuscles much more readily distinguishable.	See p. 45.

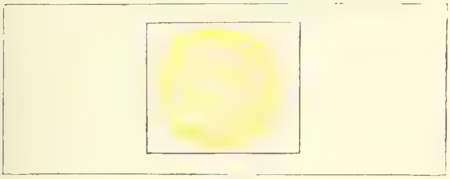

FIG. 1.

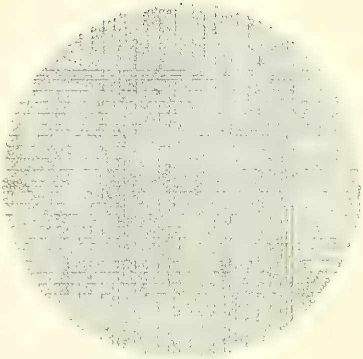

FIG. 2.

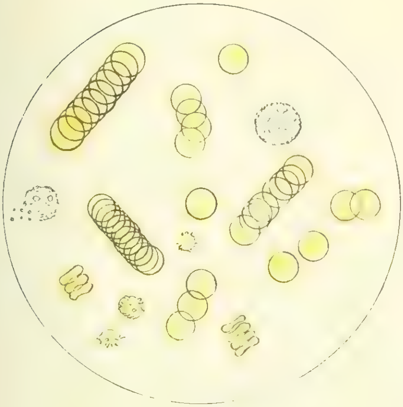

FIG. 3.

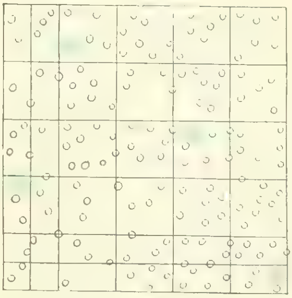

FIG. 4.

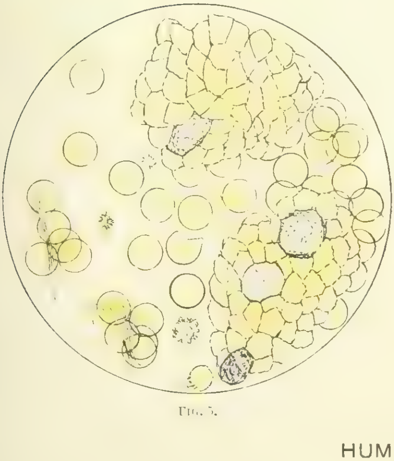

FIG. 5.

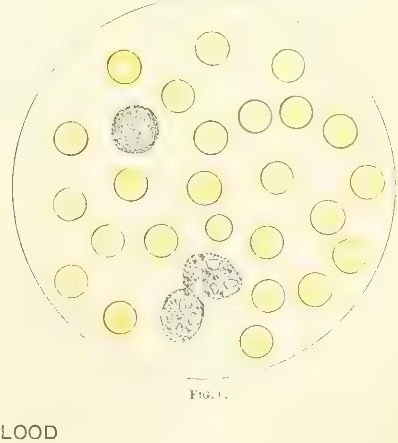

FIG. 6.

HUMAN BLOOD

1. Actual Enumeration of Blood Corpuscles.—Vierordt was among the first actually to enumerate the red blood cells; and though his apparatus was most crude and his method most complicated, yet his results have been abundantly confirmed by subsequent observers working with varied styles of apparatus. Vierordt's figures were, 5,174,000 red blood cells per cubic millimetre.

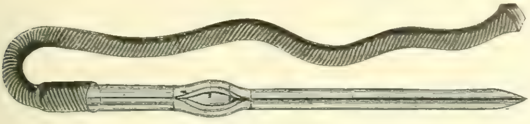

Fig. 544.—Potain's Mixer.

Vierordt diluted with a fixed quantity of sugar solution a cubic millimetre of blood and then spread this upon a slide. By means of a micrometer he counted every corpuscle. For one enumeration it took an entire week. The result of this work was to establish the following:

(1) A known quantity of blood must be taken, that quantity being the amount contained in a cubic millimetre.

(2) A known dilution.

(3) A cubic millimetre of normal blood contains 5,174,000 red cells.

At this time, Kölliker, after declaring that "owing to the difficulty of the subject" the most careful estimates can "only be described as approximate," adds: "One method only can be successful, consisting in the direct enumeration of the globules in accurately determined quantities of blood." Welker adds the next improvements (1) in using a stage micrometer, and (2) in counting the corpuscles in a fraction of a large dilution and multiplying the result of this count by the figures required to make the whole cubic millimetre.

Potain's mélangeur or mixer afforded the first means of accurately diluting the blood. This was nothing else in principle, but of cruder make, than the mixer now employed in the Thoma and Zeiss blood-counting apparatus. Fig. 544 shows this mixer.

Potain's mixer was divided precisely as is the Thoma-Zeiss mixer, into a dilated and a capillary portion, the capillary portion being exactly $\frac{1}{100}$ part of the whole. The dilated portion of the Potain mixer contained the little glass ball, as in the Thoma-Zeiss apparatus. Malassez combined this suction capillary pipette with an artificial capillary in the following manner: Blood is drawn up by suction into the Potain mixer to the 1 mark, and a diluting fluid, called the "artificial serum," consisting of —gum arabic specific gravity 1.020, one volume; sodium sulphate and sodium chloride, equal parts and each of specific gravity 1.020, two volumes—to the 100 mark, making dilution of 1 in 100. The pointed end of the mixer is then fastened to a rubber tubing connected with the artificial capillary, as seen in Fig. 545.

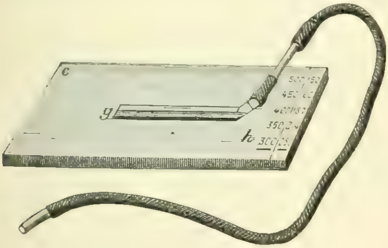

Fig. 545.—Malassez' Artificial Capillary.

The artificial capillary is set in a plate of glass which is divided into fractions of a cubic millimetre, as seen in the illustration. The microscope is adjusted so as to magnify the corpuscles as they lie in the artificial capillary (see Fig. 546), and their number ascertained for a fractional part of this capillary as marked on the glass plate. According to the fraction of a cubic millimetre which that portion selected to count represents, the number counted is multiplied.

Suppose one counts the corpuscles in $\frac{1}{400}$ of a cubic millimetre; then 400 times that number multiplied by the amount of dilution represents the number of corpuscles in a cubic millimetre.

This method offered many difficulties: 1. Complicated artificial serum for dilution. 2. Introduction of blood without air into artificial tube difficult. 3. Difficult to clean apparatus.

Hayem and Nachet devised an instrument (Hématimètre) by which the blood and serum are obtained in two separate pipettes and then mixed in a glass receiver. A drop of this mixture is then placed upon a glass slide arranged as follows: A circular well, similar to that employed in the Thoma and Zeiss apparatus, is constructed with the accurate measurement of 1 cm. in diameter and 0.2 mm. in depth. An eyepiece micrometer ruled in a large square and divided into sixteen little squares is then attached. One side of the large square measures exactly $\frac{1}{5}$ mm.* (see Fig. 547).

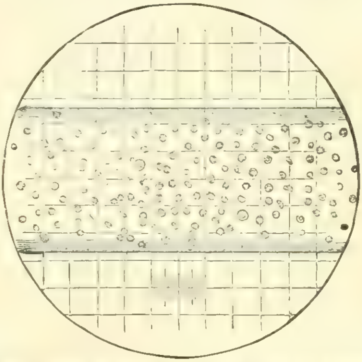

Fig. 546.—Artificial Capillary as It Appears Under the Microscope. 150 diameters. (From Ranvier.)

By counting the cells in the square and multiplying this count by the fraction of a cubic millimetre which this square represents, and the number of volumes of the diluting fluid, the number of cells in a cubic millimetre is ascertained. This

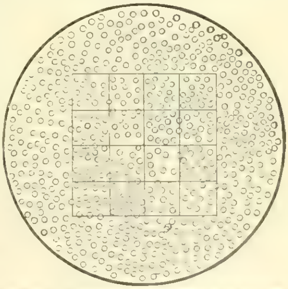

Fig. 547.—Appearance of Corpuscles with Hayem and Nachet's Instrument.

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[*] One-fifth millimetre in depth by one-fifth millimetre on two sides of square makes the block of blood one-fifth (0.2) cubic millimetre—5 × 5 × 5 = 125.

is complicated, but, as will be seen later, it has contributed certain points toward the simple apparatus used to-day.

In *The Lancet* for December 1, 1877, Gowers describes an instrument which he calls the hæmacytometer, and which more nearly approaches perfection than any already described; it therefore marks what may be considered the border line between the ancient and modern history of blood-counting by the actual enumeration method. Gowers' instrument (see Fig. 548) consists of: A, Small pipette (with rubber mouthpiece for suction) which, when filled (with diluting fluid) to the mark on its stem, contains exactly 995 c.mm. B, Another pipette marked to hold 5 c.mm. (of blood). D, Glass jar for mixing (blood and diluting fluid). E, Stirrer (to stir blood and diluting fluid in glass jar). C, Brass plate with a cell $\frac{1}{5}$ (0.2) mm. in depth and with the floor divided into $\frac{1}{10}$ (0.1) mm. squares and a cover glass held in place by springs.

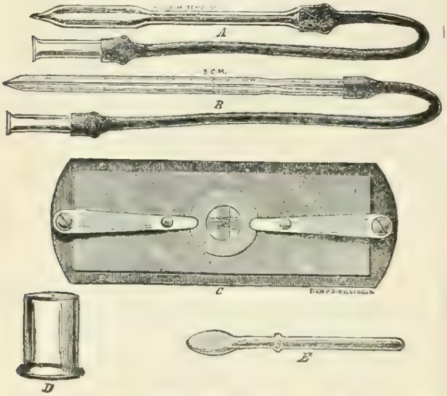

Fig. 548.—Gowers' Hæmacytometer. (From Kirkes' "Handbook of Physiology," twelfth edition.)

A standard saline solution of sodium sulphate of specific gravity 1.025 is employed; 995 c.mm. of solution is mixed with 5 c.mm. of blood with the pipettes. These are mixed in the glass jar. A drop is placed in the cell in the brass plate and the cover slip held down by the springs. The cells are then counted in ten squares, and the calculation for 1 c.mm. of which this is a fraction made.

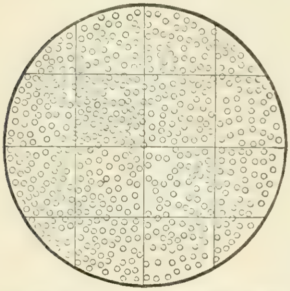

Fig. 549. Appearance of Corpuscles Under Microscope with Gowers' Instrument.

As we review these descriptions of apparatus we see that the effort of the inventors has been to overcome certain obstacles, *i.e.:*

(1) Reduction of the corpuscles to a countable number. Vierordt accomplished this by dilution and by fixing the area to be counted to the cubic millimetre.

(2) Obtaining the blood so as to prevent clot, and to dilute accurately. Welker showed the value of accurate dilution. Potain's mélangeur best accomplished this.

(3) Spreading the blood over an area thin enough to see each corpuscle. Malassez accomplished this with a long narrow tube; Hayem and Nachet with a cell whose depth was a fraction of a cubic millimetre.

(4) Mapping out the area so that the eye could navigate upon it. Hayem and Nachet accomplished this with an eye-piece micrometer. Gowers, without an eye-piece micrometer, but with a marked-out slide.

All these methods depend (as Kölliker has pointed out) upon the following priniciples: (1) A known quantity of blood for estimation (1 c.mm.); (2) a known dilution of a known quantity of blood; (3) a known fraction of a cubic millimetre to be counted.

Upon these principles and with the information obtained from the foregoing inventors, Thoma and Zeiss have constructed their apparatus. This combines the mélangeur of Potain and the mapped-out cell of Gowers.

Principle of the Thoma-Zeiss Mixer.—The mixer consists of a capillary portion and a dilated or bulb-like portion. The capillary portion enables one to procure a fixed quantity of blood that is free from clotting, if promptly taken; and the bulb portion enables one to procure a fixed dilution. The principle of this mixer is best understood by reference to the diagram shown herewith (Fig. 550).

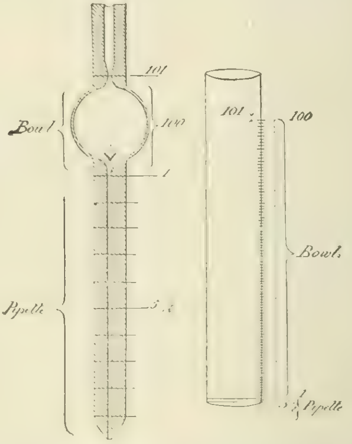

Fig. 550.—The Mixer of Thoma and Zeiss Corpuscle-Counting Apparatus. Shows principle of dilution by comparison of pipette (a necessary instrument in dealing with a coagulable fluid like blood) with an ordinary receiver (in which a non-coagulable fluid could be diluted).

Suppose the fluid to be diluted were wine or some non-coagulable fluid. Then we should pour the wine into the receiver, as shown in the diagram, up to the mark 1, and the diluting fluid up to the mark 100. This would be 1 to 100. Were we to pour the wine up to the .5 mark only (or $\frac{1}{2}$ of 1), and the diluting fluid up to 100, we should have half as much wine as before to the same amount of diluting fluid, or in the proportion of 1 to 200. Half the fluid to be diluted with the same amount of diluting fluid has the same result as doubling the amount of the latter.

Now blood cannot be poured in this way. An instrument must therefore be devised by which the blood can be taken free from clotting. Our receiver, therefore, is converted into a capillary tube and our pouring is replaced by suction. That portion of the receiver marked off as 1 is converted into the pipette, and that portion of the receiver marked off as 100 is converted into the bowl. We now have an instrument by which a definite quantity of blood can be drawn up together with a definite quantity of diluting fluid. This instrument, when full, represents 101 of blood and diluting fluid, or 1 of blood to 100 of diluting fluid. If the blood be drawn to the .5 or ½ mark and the diluting fluid to the 100 mark we have 1 to 200.

The Thoma and Zeiss apparatus is usually provided with two mixers similar in all respects except that one is larger than the other: one for counting the white cells, the larger one; and one for counting the red cells, the smaller one. That for counting the red cells is all that is necessary, and, as will be seen later, is preferable to two separate proceedings.

The diluting fluids, at first so complicated, have been much simplified. The object has been to obtain a medium as nearly as possible like that in which the corpuscles normally float.

Diluting Fluids: (1) Normal, better named physiological, salt solution.* (2) Acetic acid 1 in 300 destroys the red cells and accentuates the nuclei of the white, and is therefore valuable in counting the white cells alone. (3) By using a basic stain together with the preservative salts the results obtained separately by the other fluids are combined. The most satisfactory of these is the Toison solution.

Formula †

Sodium chloride	1.000 gm.
Sodium sulphate	8.000 gm.
Glycerin	30.000 c.c.
Water	160.000 c.c.
Methyl violet	0.025 gm.

In the preparation of this solution it is advisable first to mix the sodium chloride and sodium sulphate thoroughly, and then to add these to the glycerin and water—the methyl violet being added last. The brackets in the above formula show these steps in the preparation.

Principle of the Counting Well.—Having thus an apparatus for taking a fixed quantity of blood with a fixed quantity of diluting fluid, we must next have a means of counting the corpuscles. For this a glass slide is constructed, with a well in the centre of the following known dimensions. It must be remembered that each of the various parts of this apparatus described has been constructed to overcome an obstacle. The mixer overcame the clotting and diluted the drop, thus reducing the number of corpuscles to a countable figure. The well which we are about to describe, (1) reduces the cubic millimetre to a depth through which it is possible to see each corpuscle separately (a cubic millimetre of blood and fluid to the dilution of two hundred times would be so thick and contain so many corpuscles that the task would be beyond human skill); (2) maps out that area so that the eye can find, as it were, the longitude and latitude of any point in the sea of corpuscles.

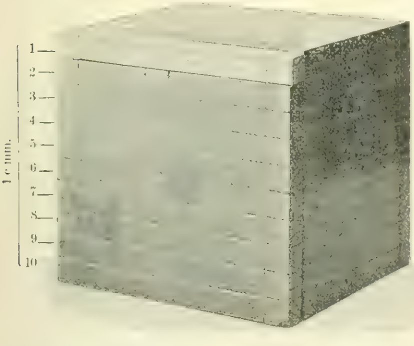

FIG. 551.—A Cube Representative of the Amount of Blood from Which Corpuscle Enumeration is Made. The block represents 1 c.mm.

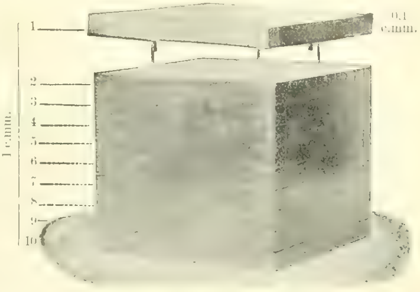

FIG. 552.

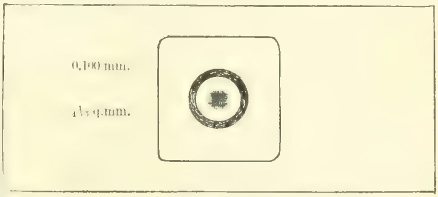

FIG. 553.—Full-Face View of Counting Stage. (Drawn by Dr. E. Dunning.) [0.100 mm. = depth 1/10 of a millimetre; 1/400 q.mm. (German quadrat-square) = smallest square which measures 1/400 of a square millimetre (25 × 16 = 400).]

What fraction of a cubic millimetre offers the depth and contains that number of corpuscles appreciable by the human eye? This fraction is found to be one-tenth of a cubic millimetre in 1 to 100 or 1 to 200 dilution of blood.

The illustration (Fig. 551) represents a millimetre cube. If this consisted of blood, the depth would be too great for the human eye to penetrate and would contain so many corpuscles as to be beyond human skill to enumerate. We therefore retain two dimensions of the cube, but take only one-tenth of the depth. This layer of blood is therefore one-tenth of a cubic millimetre in a 1 to 100 or 1 to 200 dilution (see Fig. 552).

The counting stage, to fulfil these requirements, must be constructed as follows: The bottom of the well upon which the corpuscles rest must be laid off with a square whose dimensions are 1 mm. each way, and the well must be one-tenth of a millimetre in depth. The illustration (Fig. 553) shows the full face view of the counting stage. In the centre is seen the bottom of the well with a square laid off measuring 1 mm. each way.

The second illustration (Fig. 554) shows the profile of this stage with the cover slip in place. The measurement from the under surface of the cover slip to the bottom of the well is exactly 0.1 mm.

When, therefore, a drop of the diluted blood is placed in this well and the cover slip is in place, those corpuscles which we see contained within the square, the dimensions of which are 1 mm. each way and 0.1 mm. in depth, are the contents of a cube of diluted blood measuring $\frac{1}{10}$ of a cubic millimetre.

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* Normal in chemistry indicates a solution containing the sum of the atomic weight of the salt employed in grams to 1,000 c.c. of distilled water. As this is not the case with so-called normal salt solution, the term is misapplied. Physiological salt solution is, roughly, NaCl ʒ j. to the O j. distilled water.

† This solution must be kept in the dark and must be filtered from time to time as it loses its color and develops a fungus growth which seriously plugs the pipette. This solution preserves the red cells and by means of the methyl violet stains the white cells a light purple, making the latter readily distinguishable and enabling one to make the count of both red and white cells in one process.

(NOTE.—These microscopic dimensions, but for the present simple method of construction, would render this instrument in the making a very costly and delicate affair. In the manufacture of this counting well a glass slide similar in length and breadth, but a little thicker than that employed for general microscopic work, is used. Upon a round block of glass the millimetre square is cut or pressed. This block of glass is cemented to the centre of the glass slide and forms the bottom of the counting well. Another piece of glass, like a thick cover glass but with *a round hole* cut in the centre, is cemented upon the slide, so that the block of glass already in place occupies, but does not exactly fit, the hole. The difference in measurement, from above down, between the upper surface of the round block of glass and the upper surface of the glass with the hole through it is just 0.1 mm. Thus the well with a millimetre square marked at the bottom and 0.1 mm. in depth is formed. The fact that the block of glass does not completely fill the hole in the outer piece of glass explains why there is left about it a groove into which the blood flows, if more than is required exactly to cover the block of glass is blown into the well. This seems an objection, as currents are thus produced allowing many corpuscles to flow out of the mapped area. There seems no good reason for the presence of this groove except possibly that it obviates the additional expense of making the block of glass exactly fit the hole.)

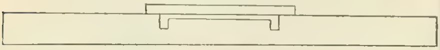

FIG. 554.—Profile View of Counting Stage. (Drawn by Dr. E. Dunning.)

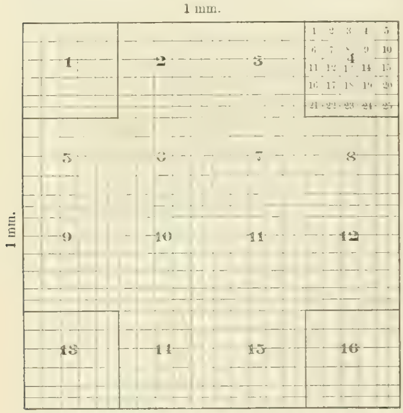

FIG. 555. Subdivisions of Counting Field of Thoma and Zeiss Apparatus. [1 sq.mm. $\frac{1}{16}$ sq.mm. $\frac{1}{400}$ (25 × 16) sq.mm.]

Principle of the Ruling of the Counting Well.—We now turn to the marking out of a millimetre square which is to render it navigable. Here, as before, an obstacle is to be overcome, viz., the inability of the human eye to keep its bearings when viewing several thousands of corpuscles.

The first subdivision of this area (as first done by Nachet and Hayem on the eye-piece and by Gowers on the stage) is into 16 squares. But even this does not overcome the difficulty, and it is necessary still further to subdivide each one of these into 25 squares (Fig. 555). It now becomes necessary to establish some boundary mark for these 16 large squares, each consisting of 25 small squares. This is done by bounding each of the 16 squares on two sides with double lines. Now we can readily count the corpuscles in one of the large squares which is bounded on two sides by the double lines, and realize that this represents $\frac{1}{16}$ of the field; or in one of the small squares, and realize that this represents $\frac{1}{25}$ of $\frac{1}{16}$, or (16 × 25 = 400), $\frac{1}{400}$ of the whole millimetre square. On the glass slide (Fig. 553) will be noticed the figures 0.100 mm., referring to the depth, which is $\frac{1}{10}$ of a mm.; also $\frac{1}{400}$ q.mm., referring to the smallest squares, each one of which measures $\frac{1}{400}$ sq.mm. ($\frac{1}{25}$ of $\frac{1}{16}$ = $\frac{1}{400}$). (Fig. 555.)

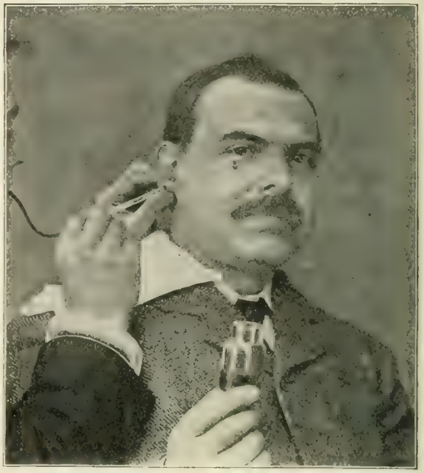

FIG. 556. Shows Method of Drawing Blood into Mixer. Diluting fluid near *at hand*.

Once these mathematical facts are clearly understood, one may count in many different ways. One small square may be counted, and the result multiplied by 400; or 25 small squares, and the result multiplied by 16. The best method,

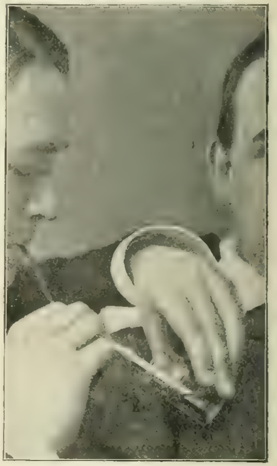

FIG. 557.—Thoma and Zeiss Corpuscle-Counting Apparatus. Drawing diluting fluid into mixer. The blood has already been drawn in.

however, will be given in the following description of the use of the apparatus.

Now that we understand the principle of the apparatus, let us proceed to its use:

In order to obtain the blood the ear is punctured as for a fresh specimen, and the tip of the capillary tube *inserted into* the drop and retained there while *gentle* suction is exerted, and the blood drawn either to the 1 mark, or the .5 or $\frac{1}{2}$ mark, as shown in Fig. 556. The latter is preferable, for the following reasons: (1) Less blood. (2) Difficult to stop sharp at the 1 mark without the blood passing on into the bowl and necessitating cleaning the instrument and beginning again. In using the .5 mark, if the blood pass the mark it may be soaked off the tip of the pipette with linen or blotting paper until the column stands opposite the .5 mark—cleaning, etc., not being necessary.

As promptly as possible, to avoid clotting, the pipette is *submerged* into the diluting fluid; and then, but not till then, suction is again made until the fluid stands opposite the 101 mark (Fig. 557). Suction must be gentle throughout, and especially so as the fluid is approaching the 101 mark, as it readily pops into the rubber tubing. The tip of the pipette must *always be immersed* in the fluid being sucked up, whether it be blood or diluting fluid, otherwise air enters the pipette and destroys the specimen.

Directly the diluting fluid has reached the 100 mark the finger is placed on the tip of the pipette and the whole shaken in order that the corpuscles may, by the aid of the small glass ball in the bulb portion of the mixer, be thoroughly mixed with the diluting fluid (Fig. 558). As the pipette contains the diluting fluid and no corpuscles, this must be emptied; and to be certain that this is done the bulb of the mixer is emptied one-third by blowing the fluid out. The diluting fluid should be allowed to act upon the blood in the mixer for five or ten minutes before the drop for counting is taken from the mixer.

The counting stage is now employed. This stage and the cover slip must be free from dust particles. The latter (the cover slip), grasped with the clamp forceps, is placed conveniently at hand. A thick cover slip with accurately level surfaces, to prevent bending, is provided with the apparatus; but as this interferes with the use of the high-power lens, it is an objection. An ordinary cover slip may be used, if care is taken not to press down upon it with the objective. From the mixer a drop is blown on to the central raised table of the counting well (Fig. 559). The drop should not (1) flow into the well, (2) or contain air bubbles, (3) or particles of dirt. The cover slip is lowered *until the fluid touches it*, then the forceps are opened and withdrawn with a jerk as in laying the cover slips for fresh specimen (see Fig. 543). There should be no air bubbles, which may be avoided by observing the foregoing precautions.

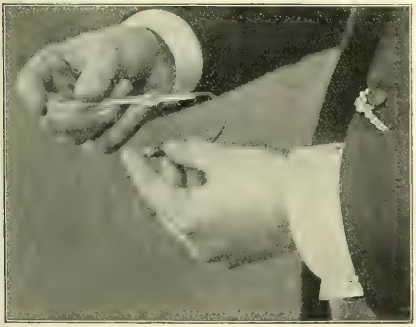

FIG. 558.—Position of Hands in Shaking Mixer.

By holding the slide up to the light *on a level with the eye* and making pressure with the point of the forceps upon the cover slip, a series of varicolored concentric rings will be seen about the point of the forceps where it touches the glass. These are the Newton's rings, which are seen only when two pieces of glass are in perfect apposition, *i.e.*, when there are no dust particles, etc., between them. The presence of these rings is therefore an evidence that the glasses are perfectly clean. Two to three minutes are now allowed for the corpuscles to sink through the depth of one-tenth of a millimetre and rest on the mapped-out bottom of the well. By at once observing the slide under the microscope this sinking process may be seen. We are now ready to count; the lowest-power lens of the Leitz or Zeiss microscope may be used. This takes in its field of vision the whole counting area, but magnifies the corpuscles so slightly that the strain upon the eye is great (see Plate XIII., Fig. 2). The 7 or 9 objective of the Leitz takes in only $\frac{1}{16}$ of the counting area, but does not strain the eye, and is therefore preferable, as with little practice the stage may be gradually moved until the whole area has been examined (see Plate XIII., Fig. 4). As the proportion of white corpuscles to red is about 1 to 700, there will be in a given area much fewer white corpuscles than red; and in the one-tenth of a cubic millimetre there will be about 3 white cells to about 2,100 red cells. The task, therefore, of picking out three white cells in an entire field will be a simple one; while it is more practicable to count only a fraction of the field containing 2,100 red cells, and then compute the total by multiplying the number counted by the fraction adopted (see Plate XIII., Figs. 2–4). The following are the steps to be taken in counting the red and the white cells:

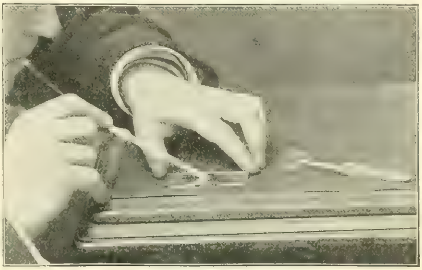

FIG. 559.—Blowing Drop from Mixer on to Stage.

Counting White Cells.—(1) Count cells contained in entire field, *i.e.*, 16 squares $= \frac{1}{10}$ of a cubic millimetre; (2) multiply by 10 to make the 1 c.mm.; (3) multiply by 100 or 200, according as the dilution has been made.

Counting Red Cells.—(1) Count 4 squares, each consisting of 25 of the smaller squares: 4 squares out of 16 $= \frac{4}{16}$ or $\frac{1}{4}$ of the whole $\frac{1}{10}$ of a cubic millimetre; (2) this number multiplied by 4 gives the number contained in the $\frac{1}{10}$ of a cubic millimetre; (3) multiply by 10 and by 100 or 200 as before.

Now it must be remembered that every time we count a fresh drop from the mixer we decrease the range of error, so (*remembering to shake the mixer well each time, as the corpuscles settle rapidly in the bulb*) suppose in counting the *white cells* we take from the mixer 5 separate drops and count each upon the counting stage. An average of the result, obtained by dividing by 5, gives us the number of white cells contained in $\frac{1}{10}$ of a cubic millimetre. This average multiplied by 10 and 100 or 200, as before, will be a more accurate figure than that arrived at by counting one drop only.

Suppose in estimating the red cells we take from the mixer and count 2 separate drops, counting in the first drop the four corner squares (Squares Nos. 1, 4, 13, and 16 in Fig. 555), *i.e.*, $\frac{4}{16}$ of the whole field; then in *the second drop* the same four corner squares, *i.e.*, $\frac{4}{16}$ also—our two counts combined will represent $\frac{8}{16}$ or $\frac{1}{2}$ of the field; this multiplied by 2 represents the whole field, *i.e.*, $\frac{1}{10}$ of a cubic millimetre. This multiplied by 10 and by 100 or 200, according to dilution, gives the number of red cells in a cubic millimetre of undiluted blood. These calculations may be expressed as follows:

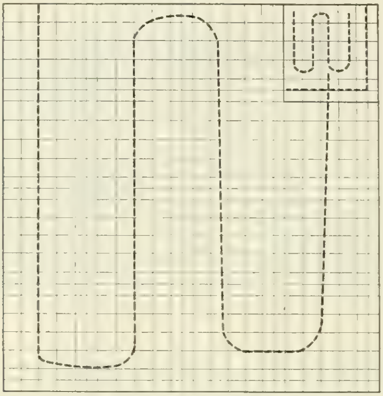

FIG. 560. Routes to be Taken in Counting Entire Field and One-Sixteenth of Entire Field.

$$\textit{White Cells}: \frac{a+b+c+d+e}{5} \times 10 \times (100 \text{ or } 200) = x.$$

a, b, c, d, and e being the counts of separate drops taken from mixer; 5 the average number; 10 for the $\frac{1}{10}$ of a cubic millimetre; 100 or 200, amount of dilution; x the number of corpuscles in cubic millimetres of undiluted blood.

$$\textit{Red Cells}: \left(\underbrace{\overset{\text{(Separate drop.)}}{(a+b+c+d)}}_{(\frac{1}{4}\text{ of field})} + \underbrace{\overset{\text{(Separate drop.)}}{(a+b+c+d)}}_{(\frac{1}{4}\text{ of field})\ \ \frac{1}{2}\text{ of field}} \times 2 \right) \times 10 \times (100 \text{ or } 200) = x;$$

a, b, c, d, each the number of corpuscles in $\frac{1}{16}$ of field—therefore together equal to $\frac{4}{16}$ or $\frac{1}{4}$ of field; plus second count obtained from another drop from mixer equals $\frac{1}{4}$ of field; and multiplied by 2 equals whole field.

One-sixteenth of the field can be readily counted by counting *inside* the double lines up and down, as in ploughing a field, and then counting along two sides *in* the double lines. The route for counting in this way is shown by the dotted lines *in the upper right-hand corner* of Fig. 560. For counting the entire field the dotted line in the whole field of Fig. 560 marks the route. This method will be found to save much time.

In order to avoid recounting corpuscles on the line, and to decide to which square these corpuscles belong, the following rule will be found valuable. Count only those corpuscles on the left line of the column down which you are counting, and in the $\frac{1}{16}$ square count only those corpuscles which lie on the double-line boundary of the square.

With practice a blood count can be made in from 15 to 20 minutes, unless the blood be from a case of marked leucocytosis or grave anæmia in which one wishes an extremely accurate count.

Cleaning the Apparatus.—The Thoma and Zeiss apparatus has received much condemnation from the difficulty experienced in cleaning it. By *strictly* observing the following rules, this difficulty will be almost wholly overcome.

(1) If by accident the blood is drawn into the bowl before being mixed with the diluting fluid, immediately draw up distilled water and proceed to clean as given below. *Do not use alcohol until all trace of blood has been removed.*

(2) Do not draw the blood into the pipette until the bottle holding the diluting fluid *is at hand* and the *cork out of the bottle* (see Fig. 556).

(3) See that the diluting fluid contains no flakes or fungus growth; if these be present, filter the fluid before using.

(4) Dry the mixer by drawing ether up and blowing it out.

(5) See that the rubber tube is free from saliva and food particles. It is well to do this from time to time, while using the apparatus, by detaching the tube from the mixer and blowing it out and then passing distilled water through it. Suppose these precautions to have been taken and the diluted specimen to be in the bowl and our count completed; we then proceed to clean the mixer.

(6) Remove the rubber tube, blow out the saliva, etc., which may have collected (see (5), above). Attach the tube *to the pipette end* of the mixer and blow out the contents of the bowl (Fig. 561).

(7) Replace the rubber tube on the large end of the mixer and draw distilled water into the bowl. Shake the mixer well and blow this water out by reversing the tube as recommended in (6), each time blowing the rubber tube free of saliva.

(8) With the tube on the big end of the mixer draw up 95 per cent. alcohol. With tube on pipette end blow this out. This removes the stain. If the glass is not entirely freed from stain, repeat until desired result is obtained.

(9) With the tube on the big end of mixer draw in ether, and then (*without* reversing tube) blow the ether out through the pipette. This shows that the whole apparatus is clear and ready for use next time.

If epithelium or mucus from the mouth, etc., gets into the bowl, it is best removed by drawing undiluted hydrochloric acid up and then introducing an especial make of wire which the writer has suggested to Messrs. Eimer & Amend to procure. It is known in commerce as "stiff brass wire, B. & S. (Brown & Sharp), No. 31 gauge," and has the advantage of being very fine but very stiff, and can be run *the whole length* of the Thoma and Zeiss mixer. With this wire, and *most decidedly* with all other wires, one must be careful to have no kinks, as these may break, leaving the wire in the mixer—an awkward accident.

In the *Deutsche medicinische Wochenschrift*, July 29, 1897, p. 497, R. Friedländer, of Wiesbaden, described an instrument, devised by himself, for counting leucocytes. He was led to the construction of this instrument by a sense of inaccuracy while using the Thoma and Zeiss counter. His objections to the latter instrument were, first, too considerable a dilution and therefore too few white cells from which to estimate; second, the calculations necessary with the Thoma and Zeiss instrument are so extensive that a small variation in the number upon which these calculations are based means an error of many thousands.

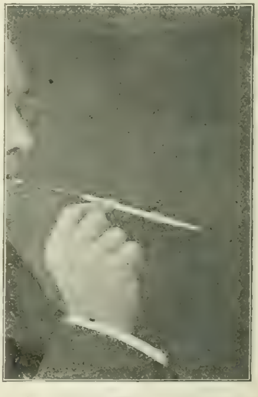

FIG. 561. Cleaning Mixer. Rubber tube on pipette end of mixer.

Friedländer confirmed these objections by obtaining different results in a number of counts of blood taken from the same individual on a single occasion. In order to overcome these objections Friedländer had Zeiss construct the following apparatus:

A pipette similar to that employed in the Thoma and Zeiss apparatus—dilution 1 in 10 or 1 in 20; a counting chamber 0.222 mm. deep × 0.3 mm. square, with the floor divided into squares—$16 \times 16 = 256$ squares in all. The double ruling is omitted; a mechanical stage is employed.

In order, by this method, to arrive at a figure expressive of the number of leucocytes in a cubic millimetre, the following formula is employed:

$$\frac{A \times Z}{M \times Q}$$

A = amount of dilution.

Z = number of leucocytes found in these sections.

M = number of sections observed.

Q = the cubic area between the floor of the counting stage and the cover slip—*i.e.*, $0.09 \times 0.22 = 0.0198$.

Example: Suppose 192 squares to have been counted and 1,522 leucocytes found; dilution 1 to 20.

$$\frac{20 \times 1{,}522}{192 \times 0.0198} = 8{,}007 \text{ leucocytes in 1 c. mm.}$$

(Note: There is a mistake in Friedländer's formula; 1,0198 should read as above, 0.0198.)

As diluting fluid he employs one-per-cent. salt solution tinged with gentian violet to which is added one-third-per-cent. acetic acid. Thus the red cells are destroyed by the acetic acid and the nuclei of the white cells intensified, and at the same time the cell is stained by the gentian violet.

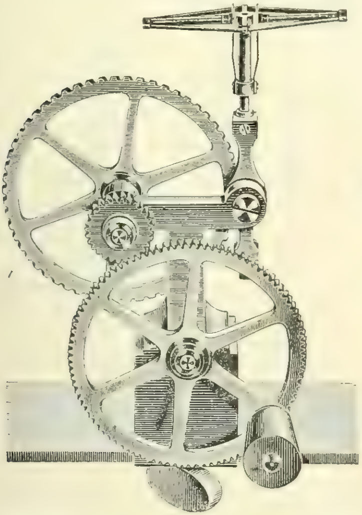

FIG. 562.—Hedin's Hæmatocrit. (From von Jacksh's "Clinical Diagnosis.")

The writer has had no experience with this instrument. If the steps as laid down in describing the Thoma and Zeiss instrument are followed the results should be as accurate.

As a clinical instrument Friedländer's would seem to be objectionable if for accuracy it is necessary to count a thousand or more cells. Unless we can arrive at accurate results by simple methods an apparatus loses its *clinical* value.

A number of counting chambers have been devised. These differ chiefly in respect of the size of their rulings; the larger ones being given the preference in order to minimize the possibility of error. The following are some of these: counting chamber of Zappert, counting chamber of Gabritschewsky, counting chamber of Miessen.

2. CORPUSCLE ENUMERATION BY MEANS OF THE CENTRIFUGE.—We now approach the task of corpuscle enumeration from a different point of view. As the corpuscles are particles floating in a fluid, we should be able to precipitate these and measure the precipitate. If, as is the case in anæmia, the corpuscles are few, our sediment should be less than in the normal. The task, then, is to throw these corpuscles down. This is done by the use of the centrifuge. This machine was employed at first to obtain serum, and its use for the latter purpose suggested its application as a corpuscle enumerator.

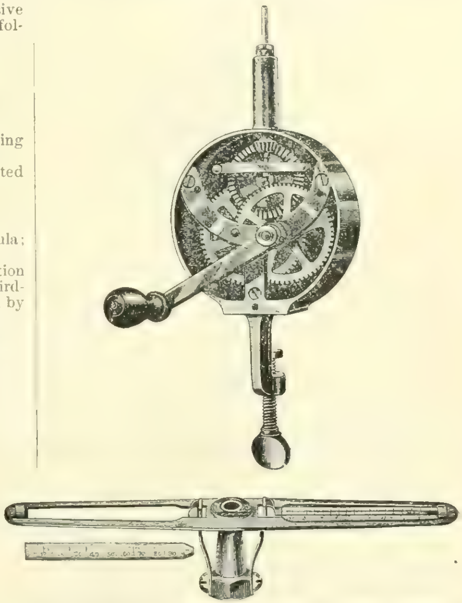

FIG. 563.—The Daland Hæmatocrit. (From Simon's "Clinical Diagnosis.")

Principle.—When blood is placed in the tube of a centrifuge and the apparatus rotated, the corpuscles collect as a red mass at the distal end of the tube and the serum as a colorless, semitransparent liquid at the proximal end.

By taking a fixed quantity of blood and subjecting it to a fixed number of revolutions for a fixed time, and by noting and marking the height of the column of corpuscles in the tube filled with blood from healthy individuals, a normal standard is determined. Deviations from this standard may be taken to indicate an increase or a decrease in the number of red cells.

By counting the blood corpuscles with the Thoma and Zeiss instrument at the same time that the blood is subjected to the centrifuge, markings to express this count may be made upon the glass tube containing the column of corpuscles.

The instrument for this method of counting is known as the hæmatocrit (*αἷμα*, blood; *κριτής*, a separator or discerner), blood separator. Hedin's instrument was among the first devised for this purpose (Fig. 562).

In using this instrument the blood is sucked into a capillary tube together with a 2.5 per cent. bichromate of potash solution or Müller's * fluid, to prevent clotting, and the tube placed in the limb of the centrifuge. The wheel is then revolved for a fixed time at a fixed number of revolutions (fifty to seventy seconds with the instrument here represented), when the red corpuscles will be found arranged as a sediment at the distal extremity of the tube, with a layer of white cells next, and above the white cells, again, the diluting fluid and serum. This instrument has been simplified very much by Judson Daland working in von Jaksch's clinic (Fig. 564). By comparing the cuts (Figs. 562, 563) it will be observed how much simpler the latter is, the principle in both, however, being the same.

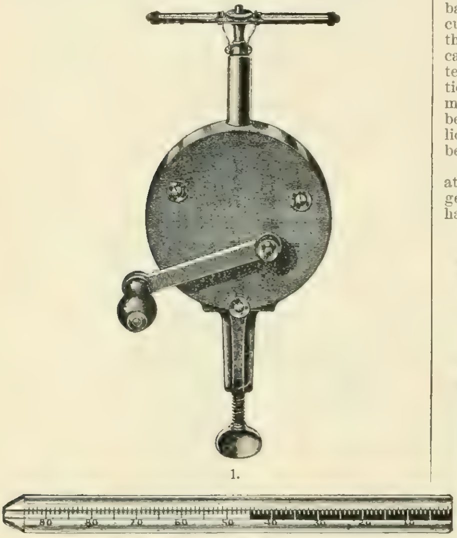

FIG. 564. Daland's Hæmatocrit. 1, The centrifuge with cross piece containing capillary graduated tubes in place; 2, capillary graduated tube (magnified) containing blood. (From Simon's "Clinical Diagnosis.")

An instrument (as shown in Fig. 565) is now upon the market for the attachment of tubes for testing blood, urine, or milk. In using the Daland instrument no preservation fluid (bichromate of potash or Müller's fluid) is employed, a questionable omission.

The instrument is operated as follows: A *large* puncture is made in the lobe of the ear in the usual way. A rubber tube is attached to the capillary tube and blood sucked up, *more than is required to fill the tube.* The index finger (with a little vaseline to prevent blood from adhering to it) is placed on the far end of the capillary tube to prevent the blood from escaping, and the rubber tube removed. The excess of blood is wiped away from the end to which the rubber tubing was attached. The capillary tube is now placed in one arm of the machine and an empty tube to balance placed in the opposite arm; then the handle of the instrument is revolved for two or three minutes. These instruments differ in the number of revolutions which they make, and each instrument should be tested to ascertain how many times it is necessary to turn the large handle in order to throw down the corpuscles so completely *that no further revolving influences them.* It is therefore impossible to give any general rule for the number of revolutions necessary beyond saying that about four thousand revolutions of the cross bar to the minute should be the basis upon which to calculate. By noting the number of revolutions made by the cross bar to every single revolution of the handle this calculation can be readily made for each machine. The test, however, as stated above, is the complete precipitation of the corpuscles. The capillary tube is then removed and the column of corpuscles noted, the count being according to the figures 2, 3, 4, 5, 6, etc., in millions opposite which the top of the column is found to be. (See Fig. 564.)

Dr. J. Metcalfe Polk, working in the clinical laboratory at the Cornell University Medical School, has at my suggestion carried out systematic observations upon the hæmatocrit, comparing it with the Thoma and Zeiss blood-counting apparatus. The instrument upon which these observations were made is that shown in Fig. 565. The following are his findings:

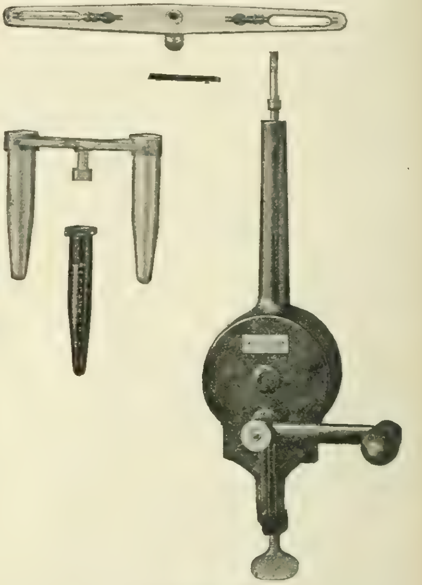

FIG. 565.—Daland's Hæmatocrit. With attachment for urine tubes as well as blood tubes.

1	2	3	4	5	
Case.	Time.	Revolution of Beam.	Reading of Hæmatocrit.	Thoma-Zeiss Count.	Remarks.
I...	1st min. 2d "	2,581 2,900	7,000,000	5,056,000	
	1 min. 30 sec.	5,075 1,450	5,200,000		
	1 min. 1 "	4,500 4,200	5,100,000		

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* Müller's fluid: Potassium bichromate, 2.5; sodium sulphate, 1.0; distilled water, 100.

1	2	3	4	5	
Case.	Time.	Revolution of Beam.	Reading of Hæmatocrit.	Thoma-Zeiss Count.	Remarks.
II...	1st min. 2d "	3,480 2,900	3,700,000	4,215,000	
	1st min. 2d "	4,350 2,900	3,900,000		Spot of corpuscles in serum at 75.
III...	1st min. 35 sec.	4,490 1,500	4,900,000	4,748,000	
	1st min. 2d "	3,580 2,900	4,950,000		Two specks of corpuscles in serum; edge at reading point ragged.
IV...	1st min. 2d "	4,300 4,200	4,500,000	4,960,000	
	1st min. 2d "	3,770 3,625	4,700,000		Corpuscles not all thrown down. Two spots in serum.
V...	1st min. 2d " 3d "	3,200 3,480 3,200	5,300,000	4,852,000	
	1st min. 2d " 3d " 4th "	3,770 3,770 3,770 3,770	5,200,000		
	1st min. 35 sec.	5,075 1,405	5,500,000		
VI...	1st min. 2d "	4,350 3,770	4,100,000	4,068,000	
	1st min. 2d "	4,060 3,770	4,200,000		Spot of corpuscles from 43 to 45.
VII...	1st min. 2d "	4,060 4,060	3,650,000	3,976,000	Spot of corpuscles 44 to 45.
	1st min. 2d "	4,060 3,770	3,500,000		
VIII...	1st min. 2d "	4,060 4,060	3,150,000	2,564,000	
	1st min. 2d "	3,770 3,900	3,400,000		From 31 to 34, corpuscles thin, but column read at 34.
IX...	1st min. 2d "	4,060 3,900	3,000,000	2,900,000	
	1st min. 2d "	3,900 3,770	3,200,000		
X...	1st min. 2d "	4,060 3,800	6,000,000	4,928,000	Spot of corpuscles from 62 to 63.
	1st min. 2d "	4,100 3,625	5,200,000		
XI...	1st min. 2d "	4,060 4,060	4,450,000	4,504,000	Corpuscles thin from 42 to 44½.
	1st min. 2d "	4,350 4,090	4,200,000		Corpuscles thin from 41 to 42.
XII...	1st min. 2d "	4,046 4,046	4,600,000	5,088,000	
	1st min. 2d "	3,800 3,770	4,800,000		Corpuscles thin from 46 to 48.
XIII...	1st min. 2d "	3,625 3,480	3,600,000	4,624,000	Case of marked jaundice. Several counts made by different people, about same results.
	1st min. 2d "	4,060 4,150	3,700,000	4,350,000	
XIV...	1st min. 2d "	4,090 3,960	4,900,000	4,968,000	
	1st min. 2d "	4,060 4,060	4,600,000		
XV...	1st min. 2d "	4,060 3,950	4,200,000	4,920,000	
	1st min. 2d "	4,060 3,900	4,700,000		
XVI...	1st min. 2d "	4,060 4,060	4,100,000	4,472,000	
	1st min. 2d "	4,060 4,060	3,700,000		
XVII...	1st min. 2d "	4,060 4,090	2,800,000	2,570,000	Per self.
	1st min. 2d "	4,060 3,770	2,600,000	2,650,000	Per Dr. Brown.
XVIII...	1st min. 2d "	4,070 3,900	1,800,000	2,200,000	Per self.
	1st min. 2d "	4,060 3,770	2,000,000	2,350,000	Per Dr. Brown.
XIX...	1st min. 2d "	4,060 4,060	4,400,000	4,900,000	
	1st min. 2d "	4,060 4,060	4,100,000		
XX...	1st min. 2d "	4,060 4,060	5,000,000	4,864,000	Per Dr. Scott.
	1st min. 2d "	4,060 4,060	5,200,000	4,656,000	Per self.

From the above tests Dr. Polk draws the following conclusions: In revolving handle of hæmatocrit the number of revolutions per minute was counted by the watch. There was no stop between the first and second minutes as indicated under the time column. The number of revolutions above a certain number, say 3,900, means very little, as it is impossible to maintain a uniform number per five seconds throughout the minute and a half or two minutes, as the case may be. If at any time the handle is turned with extra violence for ten or twenty seconds in one specimen and not so in the second, although the number of revolutions will be the same per two minutes, the reading of the first specimen will be from 4° to 8° lower than that of the second. By looking over and comparing columns 3 and 4, the above point will be evident. Time in taking a blood count with the hæmatocrit, from puncture of the finger to the reading, was on an average two minutes and forty-five seconds, or in round numbers, under three minutes; two minutes being allowed for turning the instrument. Time of a Thoma-Zeiss enumeration was over twenty-five minutes.

Time from taking the drop of blood to getting it into hæmatocrit and starting the same was never over fifteen seconds. The patient was close to the instrument. The hæmatocrit made so much noise that it could not be used in the wards.

Our conclusion as to the value of the hæmatocrit concurs with that of von Jaksch and Bleitreu, namely, that the instrument is extremely useful for routine blood work, but that in accuracy it does not equal the Thoma-Zeiss apparatus.

Our rule is to employ the hæmatocrit in routine examination, and, should a case present grave anæmia, to verify the count with the Thoma-Zeiss apparatus.

3. Enumeration of Blood Corpuscles by the Optical Method.—The third method by which the enumeration of the corpuscles is made may be termed the optical method.

The instruments used for this purpose depend for their principle upon a change in color or opacity of the blood according to its numerical value in corpuscles.

The globulimeter of Mantegazza* is the earliest of these instruments. The instrument consists of a receiver of glass with parallel walls. Into this receiver the blood is placed, after being diluted with ninety-six times its volume of a solution of sodium carbonate. A lighted candle is placed on the other side of the receiver, and the flame observed through the diluted blood. Blue glasses, one after another, are placed between the observer and the blood until the flame can no longer be detected. Each blue glass represents 125 000 red cells. From one to thirty glasses may be added, when by referring to the table the number of corpuscles will be ascertained.

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* Berliner klin. Woch., April 8, 1878; New York Med. Record, October 5, 1878.

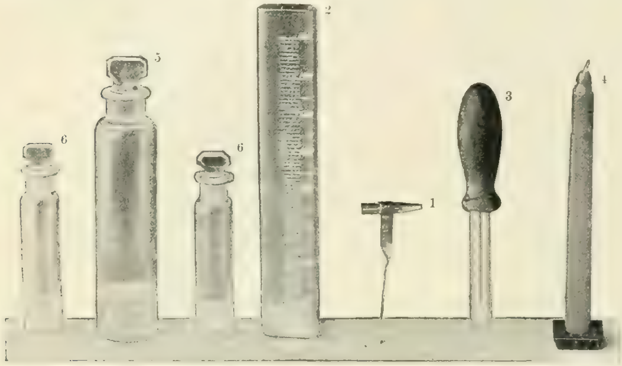

FIG. 566.—Oliver's Haemocytometer. 1, capillary tube; 2, graduated flattened receiver; 3, dropper; 4, candle and stand; 5, Bottle for Hayem's solution; 6, bottles in which to place blood and solution for subsequent examination.

Knowing, as we now do, that the amount of hæmoglobin may be far below the number of red cells, this instrument seems to be based upon a false principle. The opacity and color of the blood are separate conditions, and bear no constant relation to the number of the corpuscles.

Dr. George Oliver, of London, devised an instrument which he used in the preparation of his Croonian Lectures "On the Study of the Blood and Circulation," published in *The Lancet*, June 20, 1896. This instrument depends for its principle upon the opacity of the blood, and has nothing to do with the color or tints, so that the term tintometer, which has been applied to it, is a wrong one. The hæmocytometer of Oliver (Fig. 566) consists of the following parts: (1) A capillary tube, capacity 10 c.mm. (2) A glass receiver whose sides are flattened so that it measures less from before backward than from side to side. The tube is about four inches in length, one inch in breadth, and about one-fourth of an inch from before backward. (3) A dropper. (4) A small candle, the size of a Christmas-tree candle. (5) Hayem's solution (for formula, see p. 40).

The principle of the instrument is that in an opaque fluid (like blood), contained in a flattened glass receiver with vertical striations, to which is gradually added a less opaque fluid (like Hayem's solution), there develops, when such a receiver is placed between a candle flame and the eye, a point in the process of adding the less opaque fluid to the more opaque fluid at which the candle flame may be seen as a continuous bright line of light, which, before this point in dilution is reached, is not visible, and which after this point is passed no longer appears continuous, but as separate images of the candle flame. Moreover, the bright line of light consists of myriads of reflections of the candle flame produced by the vertical striations upon the glass receiver, which reflections cannot be appreciated by the eye of the observer until the opacity of the blood has been overcome by the addition of the less opaque solution. The point at which this line appears is constant for normal blood, from which constancy a unit may be established to measure blood rich or poor in corpuscles.

The instrument is used as follows: The skin is punctured in the usual way and the capillary tube applied to the drop as in using the von Fleischl hæmoglobinometer (see Fig. 578), the blood entering until the tube is entirely filled. There should, of course, be no air spaces in the column of blood. Excess of blood is wiped from off the sides of the tube, care being taken not to soak out the blood from the tube. This may be avoided either by not allowing the linen used to wipe away the excess of blood to touch the orifice of the tube, or by holding the finger over the upper end of the tube while wiping away the excess. The dropper is now filled with Hayem's solution and the capillary emptied by allowing the solution to squirt through the tube, as shown in Fig. 567. This can be done by inserting the pointed end of the capillary tube into the mouth of the receiver and holding the dropper close to the blunt end of the capillary, then giving a quick pinch to the rubber end of the dropper. This sends a strong stream through the capillary and empties it almost entirely. Repeating the process will certainly clean the capillary of blood. It is not necessary to attach the dropper by a rubber connection, as shown in Oliver's illustration. This is difficult and takes time, and allows the blood to clot in the capillary. We may now either proceed at once to the estimation, or the mixture thus made may be put into a small bottle and estimated at any time within twelve hours. Thus several such mixtures may be made in the course of the morning's round and placed in bottles properly labelled, the estimation being made when the physician returns to his office. Or the specimens may be sent by mail, if the distance be not such as to require more than twelve hours in transportation. These are distinct advantages over the Thoma-Zeiss instrument.

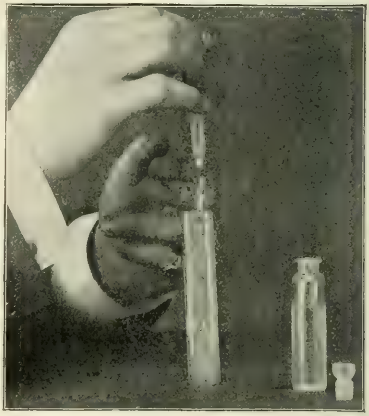

FIG. 567.—Oliver's Hæmocytometer. Washing blood with Hayem's solution from capillary tube, by means of dropper, into flattened graduated receiver.

If a candle flame ten feet away be viewed in a perfectly dark room through the receiver held as shown in Fig. 568, the receiver containing blood and Hayem's solution up to the 10 mark, for example, owing to the opacity of the mixture the flame will appear as a faint diffuse light. If now we add little by little the Hayem's solution, as the opacity becomes less the flame will become clearer, and will be caught by the vertical striations on the receiver, which act as minute mirrors to reflect the flame as a continuous line of light. When the mixture has reached that degree of opacity which allows of this phenomenon we read off the upper limit of the fluid in the receiver: 100 on the scale represents 5,000,000; 80, 4,000,000; *i.e.*, 20 on the scale indicates 1,000,000 corpuscles.

By moving the receiver slightly from side to side and from before backward, the line may be detected at the sides a little before it extends across the receiver, a signal to the observer to add the solution cautiously drop by drop. Before the fluid has reached the height at which the line appears continuous the line is noticed to be blurred. As we add more fluid than is necessary to produce the continuous line, the line ceases to be a continuous one and becomes a series of minute but separate images of the candle flame. The point, therefore, at which the reading should be made is *after the line ceases to be blurred and before separate images of the flame can be observed.* The candle should be at least ten feet away and should be not larger than the ordinary Christmas-tree candle. The receiver should be held in the right hand and the thumb pressed well into the side of the nose so as to shut off all diffused light, as shown in Fig. 568

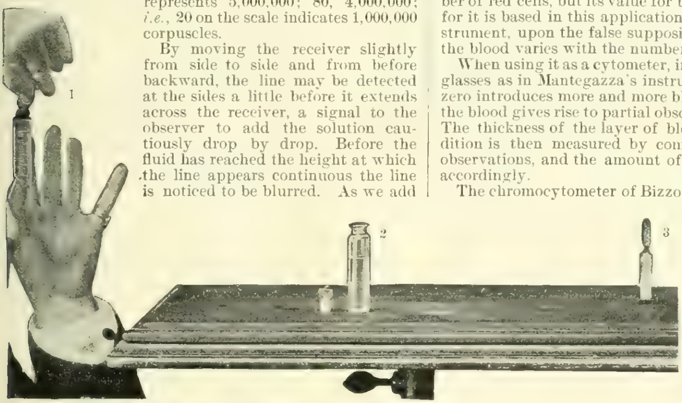

FIG. 568. Oliver's Hæmocytometer. Watching for that degree of opacity at which candle flame will be seen as transverse bright line across flattened receiver. 1, Holding flattened receiver close to eye, between thumb and forefinger of left hand, while adding Hayem's solution from dropper with right hand; 2, bottle holding Hayem's solution; 3, candle ten feet away from observer and on a level with observer's eye.

III. HÆMOGLOBIN ESTIMATION.

Apparatus and Technique.—The task of estimating the amount of hæmoglobin has long been an unsatisfactory one, because all methods, excepting only the specific-gravity method, depend upon the comparison of colors, a subject upon which nearly all individuals differ, and upon the degree of opacity, which is supposed to vary with the amount of hæmoglobin, a supposition by no means proven.

The instruments group themselves into three classes, as follows:

1. Bizzozero's chromocytometer 2. Henoque's hæmatoscope.....	Based upon the supposition that the amount of hæmoglobin varies with the degree of opacity.
1. Gowers' hæmoglobinometer 2. Von Fleischl's " 3. Von Fleischl's and Meischer's " 4. Taylor's " 5. Oliver's tintometer "	Based upon the supposition that the amount of hæmoglobin varies with the intensity of color.
1. Hammerschlag's method 2. Roy's "	Based upon the supposition that the amount of hæmoglobin varies with the specific gravity.

1. OPACITY METHODS.—*The Chromocytometer of Bizzozero** depends for its principle upon the supposition that the opacity of the blood varies with the amount of hæmoglobin.

The instrument may also be used to estimate the number of red cells, but its value for this purpose is doubtful, for it is based in this application, as is Mantegazza's instrument, upon the false supposition that the opacity of the blood varies with the number of cells contained.

When using it as a cytometer, instead of adding colored glasses as in Mantegazza's instrument (see p. 49), Bizzozero introduces more and more blood until the *opacity* of the blood gives rise to partial obscuring of a candle flame. The thickness of the layer of blood producing this condition is then measured by comparison with standard observations, and the amount of hæmoglobin estimated accordingly.

The chromocytometer of Bizzozero is an instrument intended primarily for the estimation of hæmoglobin. The name is misleading. The instrument is so called because the amount of hæmoglobin is ascertained by two methods: (1) By observing the degree of opacity produced by the hæmoglobin *unremoved* from the corpuscle, and therefore the actual corpuscular value of hæmoglobin—in which application it is called a *cytometer* (*κύτος*, a cell; *μέτρον*, a measure). It does not number the corpuscles, as at first the name seems to imply. (2) By observing the color produced by the hæmoglobin removed (dissolved) from the corpuscle and comparing this color with a standard colored glass—in which application it is called a chromometer (*χρῶμα*, a color; *μέτρον*, a measure). Its application as a hæmocytometer is a wrong one, as already stated.

As a Cytometer (term understood as above described).—*Principle:* If a fixed quantity of blood be mixed with a fixed quantity of preserving fluid (saline solution), and the mixture placed in a receiver, and a candle flame viewed through the mixture in a dark room, then, according to the amount of hæmoglobin and the amount of the mixture used, the flame of the candle will either be seen or will not be seen. By observing the amount of this

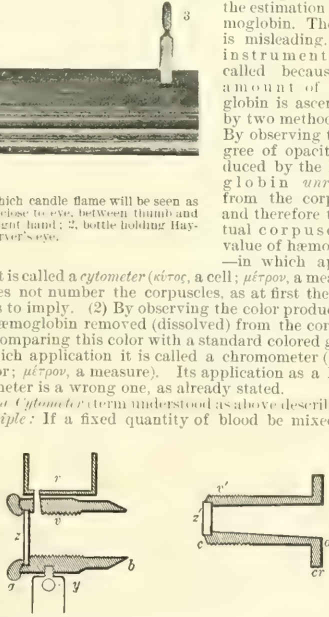

FIG. 569.—Diagram Showing Construction of Bizzozero's Chromocytometer. v, Well connecting with r, chamber formed by r′, which screws into r; z and z′, glass windows.

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* Atti della regia Accad. d. Sc. di Torino, xiv., 1879.

mixture necessary, in normal cases, partially to obscure the candle, and calling this 100, we can, as more or less of such a mixture is required in diseased cases, ascertain the decrease or increase in the amount of hæmoglobin.

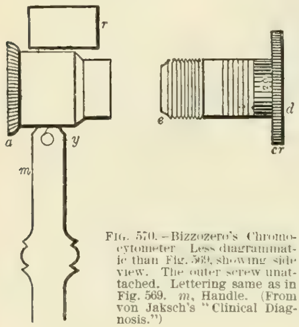

FIG. 570.—Bizzozero's Chromocytometer Less diagrammatic than Fig. 569, showing side view. The outer screw unattached. Lettering same as in Fig. 569. *m*, Handle. (From von Jaksch's "Clinical Diagnosis.")

The instrument consists of a well which *connects* with a chamber closed at both ends with colorless glass. The chamber consists of two pieces of metal, one screwing into the other. These are hollowed out so as to form the chamber within (Fig. 569). By screwing or unscrewing one of these pieces the dimensions of the chamber may be decreased or increased. It will be seen that if diluted blood be placed in the well which connects with this chamber, the blood will flow into the chamber through this connection. But only just so much blood will flow into the chamber as is allowed by unscrewing the outer screw. When the outer portion of the instrument is screwed home (Fig. 571) no fluid at all enters the space between the screws—in other words, the chamber is then obliterated. Now by unscrewing or screwing the piece of metal which fits into the other piece and which, together with its fellow, forms the chamber, we can increase or decrease the amount of fluid in the space between the screws.

(1) Suppose now the two pieces of metal to be completely screwed together, so that no space exists between them, the scale then stands at 0. (2) We fill the well (Figs. 569–571, *r*) with 50 parts of normal saline solution to 1 part of blood; or, to be more accurate, by means of a pipette we mix 10 c.mm. of blood with 0.5 c.c. saline solution (0.75 gm. of NaCl in 100 c.c. water), which preserves the corpuscles. (3) A candle is placed in a dark room about four feet away from the observer. (4) The instrument is held by the left hand and close to the right eye, opposite the candle. (5) The two ends of the chamber, it will be remembered, have glass windows, so that the candle flame will be clearly seen. (6) With the right hand the pieces of the metal are slowly unscrewed, which allows the blood to flow from the well into the chamber. (7) As we introduce more and more fluid into the chamber, however, a degree of opacity must be reached at which the candle flame will be almost or wholly obscured. This is just what occurs. By observing the degree of unscrewing, so to speak, necessary to produce this opacity for normal blood, we obtain a unit with which diseased blood may be compared. By means of the table given below the amount of hæmoglobin may then be ascertained.

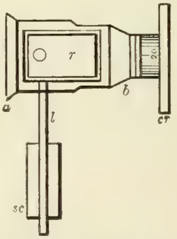

FIG. 571.—Bizzozero's Chromocytometer. Screws completely screwed together, obliterating chamber. Well viewed from above. In this position one looks into the well. The round ring represents the connection between well and chamber. (From von Jaksch's "Clinical Diagnosis.")

When the space between the glass windows is obliterated by screwing the outer portion home, the index on the scale stands at 0. One complete rotation of the screw produces a space in the instrument measuring 0.5 mm. This is therefore the thickness of the contained solution of blood. One complete turn, however, renders the candle flame decidedly less visible. This complete rotation is therefore subdivided on the scale into 0.02 mm., 25 such subdivisions (0.02 × 25 = 0.5) constituting one complete revolution, and 50 such subdivisions (0.02 × 50 = 1.0) constituting 1.0 on the scale. From a number of observations (as stated by von Jaksch) upon the blood of healthy individuals, the outlines of the candle flame are distinctly seen through a layer of blood $\frac{110}{100}$ mm. thick = 1.0.

This, then, is the unit; *increase* of this number means *decrease* in amount of hæmoglobin. For if we must increase the thickness of the stratum of blood in order to obscure the candle flame, it indicates that the fluid is poor in coloring matter, and that an excess is required to produce dimness of the candle flame.

Scale.		Hæmoglobin.	Scale.		Hæmoglobin.
110	represents	100.0	170	represents	64.7
120	"	91.6	180	"	61.1
130	"	84.6	190	"	57.9
140	"	78.5	200	"	55.0
150	"	73.3	210	"	52.4
160	"	68.7	220	"	50.0

If one has not this table at hand the reading can be readily interpreted by remembering that 110 = 100. Suppose, for example, the reading to be 160 on the scale; then:

$$100 : 110 :: 160 : ?$$
$$100 \times 110 \div 160 = 68.7$$

As a Chromometer (term understood as above described).—In addition to the parts of the instrument as already enumerated, there is a colored glass (see Fig. 572). This is introduced on one side of the instrument so that the colored glass and the glass windows of the instrument are *side by side*, as would be the case with a pair of opera glasses if one side were to consist of only the eyepiece, and that with a colored glass in it. In this use of the instrument, moreover, the hæmoglobin is dissolved out with water in preparing the blood for observation.

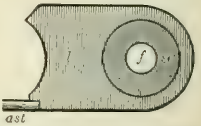

FIG. 572.—Bizzozero's Chromocytometer. Frame holding tinted glass. This is placed by the side of the screw of the main apparatus. *f*, Tinted glass; *l*, frame; *ast*, rod which passes through hole *y* in handle *m* of Fig. 570.

Principle: If a glass colored to correspond with a definite solution of hæmoglobin be placed before a bright light (the sky) and beside a solution of hæmoglobin to be tested, the color of the tinted glass and that of the solution of hæmoglobin will be found to differ. If, however, more or less of the solution be added, a point will be reached at which these colors correspond. By noting the amount of solution required to make these colors exactly correspond a scale may be made by which the amount of hæmoglobin may be estimated.

Given a tinted glass which corresponds in color with a known solution of hæmoglobin. Given a known quantity of blood (10 c.mm.) with a known quantity of water (0.5 c.c.). If the blood to be tested contains much coloring matter (hæmoglobin), it will be necessary to add but little of the solution in order to make the colors correspond; if it contains little coloring matter, much will be required to make these colors correspond. These quantities are noted and compared with a scale, each quantity of fluid corresponding with a percentage of hæmoglobin.

By referring to Figs. 570 and 571, the working of the apparatus will be readily understood.

The colored glass is not of the same intensity of color in every instrument, so that the glass must be tested for each instrument.

The test is performed in the following way: Normal blood is tested, and is found to be, by the cytometer method, 110, and by the chromometer, say 130. One hundred and ten of the cytometer equals 100 hæmoglobin. For this glass, then, 130 also equals 100.

As in the case of the cytometer method, we construct a table from these relations. Suppose the reading with the chromometer to be 190.

$$100 : 130 :: 190 : ?$$

$$100 \times 130 \div 190 = 68.4.$$

After a brief experience in using this instrument the author is inclined to commend it.

Henocque's Hæmatoscope.—This instrument also depends for its principle upon the supposition that the amount of hæmoglobin varies with the degree of opacity of the blood. In this instrument, in addition to the degree of opacity, the quantity of oxyhæmoglobin is ascertained by means of the spectroscope. This latter method places the instrument among the apparatus of an elaborately equipped laboratory and diminishes its value for bedside work. Moreover, as von Jaksch states, there is a "difference of opinion as to when precisely the spectrum is formed," making the conclusion drawn from the use of the instrument "always somewhat arbitrary."

The instrument consists of two plates of glass, one placed above the other so as to enclose between them a prismatic space. The dimensions of this space are accurately stated and are the same for every instrument.

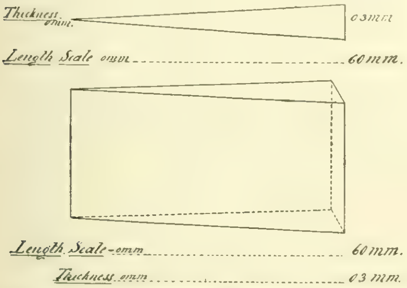

FIG. 573. Henocque's Hæmatoscope. Diagram showing dimensions of prismatic space formed by plates of glass.

These plates of glass are in contact at one end, forming the apex of the prismatic space. The scale of measurement at this end is therefore 0.

At the other end the glass plates are separated by a distance of 0.3 mm., forming the base of the prismatic space. By referring to the diagram (Fig. 573) and illustrations (Figs. 574 and 575), this arrangement will be readily understood.

The scale upon the glass is marked from 0 to 60, as observed in Fig. 574.

There are two methods of using the instrument.

(1) The first method is based upon the supposition that varying opacity of the blood differs according to varying quantity of hæmoglobin, so that by observing the former the latter may be estimated.

To use the instrument upon this basis, puncture is made in the skin in the usual way and the drop brought to the orifice of the prismatic space, which, from its dimensions, will be observed to be capillary. The blood on this account passes readily into the space without being diluted, an advantage over the dilution methods.

About six drops of blood are necessary to fill the space. Excess is wiped away.

In addition to the apparatus already described, there is an enamelled plate, as seen in Fig. 575.

This plate is placed behind the prismatic layer of blood, so that the figures 0, 10, 20, etc., correspond with the like figures on the glass plate of the hæmatoscope. At the apex end of the prism, and therefore at the thinnest portion of the layer of blood, the marking on this enamelled plate will be visible; but as the eye passes toward the thicker portion of the prism of blood a point will be reached at which the marking can no longer be seen. If the blood tested be rich in hæmoglobin the opacity will be greater, and therefore the point in the series 15, 14, 13, 12, etc., at which this obscuring occurs will be higher, say 11 or 12, as seen in the illustration. If, on the other hand, the blood be poor in hæmoglobin, the opacity will be correspondingly less, and we shall be able to see the figures 10, 9, 8, etc., in the series.

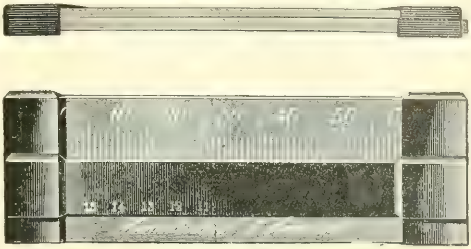

FIG. 574.—Henocque's Hæmatoscope Filled with Blood. (From von Jaksch's "Clinical Diagnosis.")

One hundred grams of normal blood contain 14 gm. of oxyhæmoglobin. These figures, therefore, indicate the number of grams of oxyhæmoglobin in 100 gm. of blood. For this use the author commends the instrument.

(2) The second method is based upon the supposition that the richer the blood is in hæmoglobin the thicker will be the layer necessary to detect through the spectroscope the characteristic bands of oxyhæmoglobin. By noting the thickness in normal blood at which the oxyhæmoglobin spectrum occurs, a scale may be made with which deviations from the normal may be measured. The apparatus, with the exception of the enamel plate, is used as before.

The prism is fitted in front of a spectroscope and is turned until the oxyhæmoglobin bands appear, when this point is noted on the scale. With normal blood the oxyhæmoglobin spectrum is seen opposite 14 of the millimetre scale. Now for every millimetre on the scale the thickness of the prismatic space increases 0.005 mm. This can be demonstrated by multiplying 0.005 by 60, the length of the scale; the result is 0.3 mm., the thickness of the prism at its base, *i.e.*, at the 60 mm. end. As, therefore, for normal blood the spectrum appears at 14 on the millimetre scale, we determine the thickness of

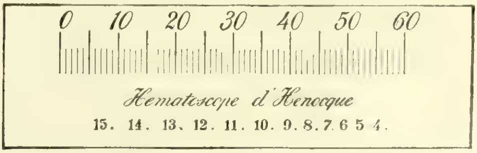

FIG. 575.—Enamelled Plate Used with Henocque's Hæmatoscope. (From von Jaksch's "Clinical Diagnosis.")

blood required to produce this spectrum by multiplying 14 mm. × 0.005 mm. = 0.07 mm.

This, then, is a unit; it is the thickness of normal blood required to produce the oxyhæmoglobin spectrum.

Suppose a specimen of blood produces the oxyhæmoglobin bands at 40 on the millimetre scale. The thickness of this specimen would be 40 mm. × 0.005 mm. = 0.2 mm. Then:

i.e.: $\frac{0.07 \times 14}{0.2} = x = 4.9$ gm. of hæmoglobin in 100 gm. of blood.

An equation for any reading is the following:

$$(y \times 0.005) : 0.07 :: 14 : x$$

in which

y = reading on the scale.

0.005 = thickness of prism for each millimetre division on the scale.

0.07 = thickness of layer of normal blood by which oxyhæmoglobin spectrum is produced—*i.e.*, at 14 on the scale (14 × 0.005 = 0.07).

14 = quantity of oxyhæmoglobin in 100 gm. of normal blood.

From these calculations one can make for himself a table which will at once give him the amount of the hæmoglobin for any reading on the scale. Thus beginning with 5 on the millimetre scale, and substituting it for y in the equation, we get the following:

$$(5 \times 0.005) \times 0.07 \div 14 = 12.5.$$

Therefore 5 mm. of the scale = 12.5 gm. hæmoglobin in 100 gm. of blood.

If we substitute in the same way 10, 15, 20, etc., the table becomes complete.

The instrument has not been much used in this country, and, as already stated, except for the opacity method, it requires more apparatus than would be practicable at the bedside.

The author has not had sufficient experience with this method to express an opinion upon its value.

2. Color Methods.—Before entering upon the description of those hæmoglobinometer instruments which depend for their principle upon the comparison of colors, it would be well to quote from Lovibond's very interesting and valuable work on "Measurements of Light and Color."

"It is almost impossible," says Lovibond, "without special arrangements to arrive at a reliable judgment between two colors which are very nearly, but not quite, alike, when these are placed openly side by side. The difficulty arises from the unequal incidence of light—sometimes of the direct light, frequently of the side lights, or from both combined. The disturbing effect is so great that a slight change of position in either of the samples, or of the observer, generally reverses the first judgment.

"The same causes account for the *frequent differences of opinion between two persons* judging the same color; in fact, the color sensations of our surroundings are . . . governed by the ever-varying conditions of light, surface, substance, texture, and chemical composition. . . ."

The following are the experiments carried out by Prof. Lovibond:

"*Test Tubes containing colored liquids.*—The first attempts were made with colored liquids in test tubes of equal diameters, and by these means some useful information was obtained. The liquids, however, *soon changed color*, requiring frequent renewals; and there was always a little uncertainty concerning their exact reproduction. Also a curious inequality of color relation was found to exist between the regular increase of strata thickness and their resulting color. This prevented liquids from being suitable as standards, because some liquids increase in color depth in direct proportion to increase of strata thickness. Some increase in color in a less but regular proportion to increase of strata thickness, whilst others increase in a less and irregular proportion.

Another difficulty arose from the convex surfaces of the test tubes acting as a lens, and increasing the disturbance arising from unequal light incidence. The convexity was reduced by using larger tubes, and enclosing them in a blackened case with narrow longitudinal apertures for looking through the middle of the tubes. The results, although useful, were too unsatisfactory for systematic work.

"*Colored glass* was next tried, and long rectangular wedges in glass of different colors, with gradually graded tapers, were ground and polished for standards, whilst correspondingly tapered vessels were made for the liquids to be measured. These were arranged to work, at the end of the instrument, up and down at right angles before two apertures, side by side, with a fixed centre line to read off the thickness of each before the aperture when a color match was made; but here also the difference of ratio between the thickness and color depth of the different colored glass and liquids proved fatal to the method.

"An incidental observation was made during these experiments concerning the difficulty of arriving at a final judgment with tapering colors, owing to one shade gradually blending into the next without a break of any kind to arrest the vision. The mental effort to arrive at a decision, under these conditions of gradual color-blending, was troublesome and vexatious in the extreme. Any person may realize this difficulty by attempting to fix a definite point by the vision in a graduated color line. I was enabled entirely to remove the difficulty by using separate glass slips for standards; the line of color decision made by each additional standard-glass slip used being a precise definition between the most minute shades.

"The effect of these partial failures enabled me more clearly to define the conditions from which successful work might be expected, which are as follows:

"*Gauged Cells.*—The cells for the liquids must have parallel transparent ends and be gauged to definite strata thickness.

"*Optical Instrument.*—The standard and sample must be viewed under equal conditions of illumination.

"*Suitable Light for Color Work.*—Considerable differences of view exist concerning the most suitable light for color work. Some authorities consider that daylight is too unreliable in composition, and that an artificial light, such as the electric arc, is best, as being always uniform.

"Captain Abney's work and apparatus at first sight go a long way toward establishing this view. Some valid reasons, however, in my opinion, exist in favor of daylight; as it is the light to which normal vision is most accustomed, and it is available, without cost at a moment's notice, during daylight hours, whereas artificial lights require to be worked in camera with somewhat expensive apparatus. Again, by far the largest proportion of artistic and commercial color work is carried on by daylight, so that measurements made by means of any other light must be transposed into terms of daylight values before reliable comparisons can be made. Without doubt the vision can work longer and with less fatigue by daylight than by intense artificial light."

From the foregoing it will be seen that liquids and colored glasses have a distinctive color value, and that any method which employs blending colors, as the colored prism of the von Fleischl apparatus or the gradually diluted blood in the Gowers instrument, presents a wider field for error than that method which employs fixed and uniform colors for comparison. Also daylight is the most reliable.

Gowers' Hæmoglobinometer.—This instrument is one of color comparison.

Principle: If a colored fluid representing a very low percentage of hæmoglobin be placed by the side of a solution of a fixed quantity of blood, to which water is added little by little, a point in the process of dilution will be reached at which the two colors correspond.

By observing the amount of diluting fluid required to bring normal blood to a corresponding color with the fixed color, a scale may be made by which deviations from the normal may be detected.

The parts of the instrument (Fig. 576) are (numbers correspond with those in cut): 1. A solution of picrocarmine glycerin of the color of a one-per-cent. solution of normal blood, contained in a sealed tube. 2. An open tube graded from 10 to 120. 3. A pipette measuring 10 and 20 cm. 4. A dropper.

To use the instrument: A little water is put into the graduated tube. Puncture of the skin is made in the usual way, and blood drawn up to the 20 c.mm. mark. The blood is at once blown into the graduated tube containing the water. The blood and water are then thoroughly mixed, and more water, little by little, added by means of the dropper until the color of the diluted blood and that of the standard solution correspond. It will be seen that if the blood is rich in hæmoglobin it will be necessary to add a large quantity of water in order to make it of the color of the standard solution, which represents only one per cent.

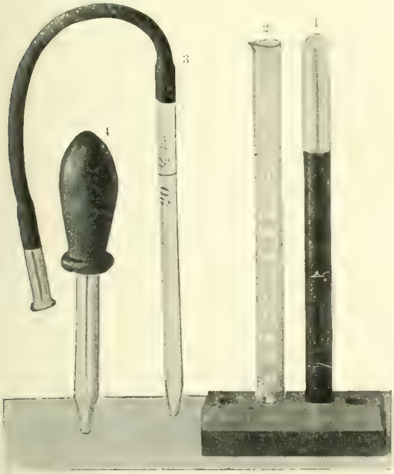

FIG. 576.—Gowers' Hæmoglobinometer. 3. Capillary tube for taking a definite quantity of blood; 4. dropper for adding water; 2. graduated receiver for blood and water; 1. tube containing picrocarmine, color equal to that of blood with one per cent. hæmoglobin.

As we add more and more water, however, the column of fluid rises on the scale, and therefore indicates a high percentage of hæmoglobin. In cases of anæmia the correspondence will be sooner reached, and the column of fluid will stand at a lower level in the tube, and will therefore indicate a low percentage of hæmoglobin.

This instrument has the advantage of being cheap as well as accurate.

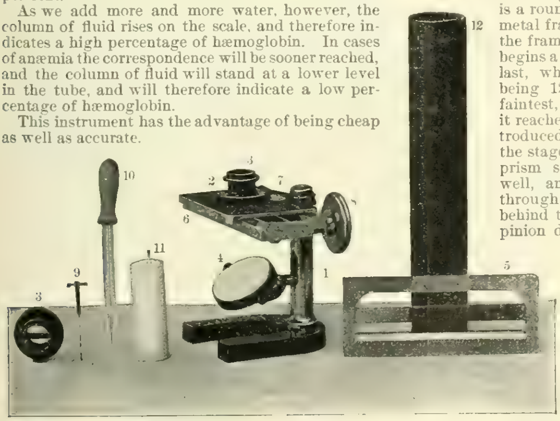

FIG. 577.—Von Fleischl's Hæmoglobinometer.

The standard solution, picrocarmine, changes color in time, a point noted by Lovibond and by Oliver working in Lovibond's laboratory.

Von Fleischl's Hæmometer—or, more correctly, hæmoglobinometer—depends for its principle upon the supposition that a solution of hæmoglobin varies in color according to the amount of hæmoglobin which it contains, and that the latter may be measured by comparison with the varying colors in a prism of glass, each degree of color corresponding to a percentage of hæmoglobin

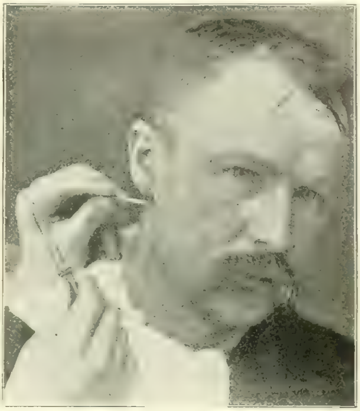

FIG. 578. Von Fleischl's Hæmoglobinometer. Taking drop of blood in capillary tube.

We must keep in mind that when water is added to blood the hæmoglobin is dissolved out of the corpuscles, and it is the colored solution which we are comparing, not the hæmoglobin as contained in the corpuscles.

The parts of the instrument are (numbers correspond with those in illustration, Fig. 577): A stand (1) with a horseshoe base. A stage (2) with a round hole in the centre for the reception of (3) a well 1.5 cm. in depth and divided into two equal parts; the bottom of this well is closed by a piece of clear glass. Below the stage is a round reflector of plaster of Paris (4). In a metal frame is a prism of colored glass (5). On the frame opposite the apex of the prism there begins a series of figures, the first being 0 and the last, which is opposite the base of the prism, being 120. At 0 the tint of the color is the faintest, this tint increasing in intensity until it reaches the maximum, 120. The frame is introduced into two tracks (6) which run below the stage. It is placed so that the colored glass prism shall pass beneath one division of the well, and the series of figures shall appear through an oval opening (7) in the stage just behind the well. By means of a rack (8) and pinion different parts of the varicolored glass prism may be made to pass along the bottom of one division of the well, and at the same time the figures indicating the color intensity of the glass at that point will appear in the oval opening behind the well. There are also a capillary tube (9) by which a fixed quantity of blood may be obtained; a medicine dropper (10), a candle (11), a black tube (12) to shut off the surrounding light from the eye.

We have, therefore: 1. A colored

glass varying in tint with known quantities of hæmoglobin. 2. A well divided into two equal parts of known depth. 3. A capillary tube of known capacity.

The instrument is used as follows:

Puncture is made in the usual way and the tip of the capillary tube touched to the drop, as seen in illustration (Fig. 578). No air space must occur in the tube. If the drop at first taken is not enough to fill the tube, in adding more, care should be exercised that the blood is flush with the end of the tube before again touching it to the blood drop. By gently tapping the tube this can be accomplished.

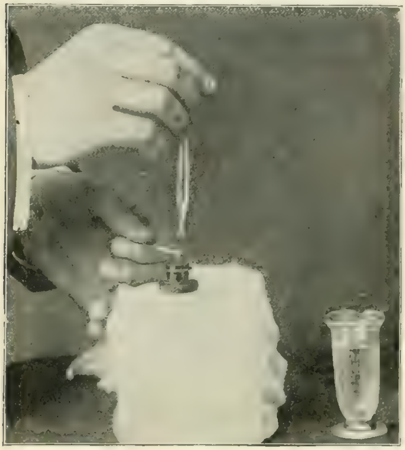
FIG. 579. - Von Fleischl's Hæmoglobinometer. Washing drop of blood from capillary tube with water into one side of double well.

When the tube is quite full we *at once* insert the end into one of the subdivisions of the well, and with the medicine dropper send a stream of clear water forcibly through the tube (Fig. 579). This must be done promptly or the blood will clot in the capillary. The dropper need not be fitted on to the capillary tube, a procedure which often causes the latter to break. If the stream of water has been sent through with sufficient force the capillary will be entirely freed from blood. We then fill the well by dropping water with the dropper through the capillary. This fills the well and at the same time makes sure that all the blood has been washed through.

When the water has reached the top of the well a meniscus, which cannot be avoided, will be observed. When, however, we fill the opposite well with clear water, which we shall proceed to do directly, we must see that the meniscus in each well is of the same depth.

If the well should be full before all the blood has been washed from the capillary tube, then the dropper emptied of the water may be filled with the diluted blood already in the well and this passed through the capillary tube again until the latter is free of all trace of blood. Then the capillary tube is immersed into the well and the contents of the well stirred.

The other subdivision of the well is now filled with clear water, care being taken not to allow the contents of the two wells to mix over the division wall; also that the meniscus in each is of the same depth, as already mentioned.

Attention is called to the fact that the upper portion of the well unscrews for the purpose of cleaning the glass window at the bottom. These two portions should be tightly screwed together before using, so that the fluids will not mingle at the bottom of the well. Moreover, though the wells are the same in all instruments, the prisms of glass vary one from the other in intensity of color. It is necessary, therefore, for the maker to test each prism and ascertain *what is the amount of normal blood* which will correspond to the color opposite the 100 mark. This amount is fixed by the capacity of the capillary tubes. Hence it follows that the capillary tubes tested for a certain instrument should be used only with that instrument. To insure this, the number upon the handle of the capillary tube should be observed, to see that it corresponds with the number on the screw of the stand, just behind the round opening for the well. Then, again, the prism of glass must correspond with the stand, and this is insured by seeing that the number on the stand and that on the metal frame of the glass prism are the same.

The above is a most clumsy method of numbering, arising probably from the fact that different workmen make different parts of the same instrument. The point to be borne in mind is that *the glass prism and the capillary tube must correspond*, and this can be made certain only by observing the above unnecessarily complicated system of numbering. *The wells are of the same depth in all instruments.* The figures on the handle of the capillary tube refer to the capacity of the tube.

We have now filled the two divisions of the well, the one with clear water, the other with a fixed quantity of blood and water.

The frame with the glass prism is now put in place, and the well over the prism, so that the prism shall be opposite that division which contains the clear water.

We now transfer our operations to a dark room lighted only by a small candle. The instrument is placed about eighteen inches away from the candle, and a dark tube is placed over the well in order to shut off the surrounding light from the eye. The plaster-of-Paris reflector is adjusted so as to throw the light into the well, and then the screw of the glass prism frame is turned until the color of the diluted blood and that of the the colored glass correspond (see Fig. 580). The figure which appears in the oval opening is now read, and this is taken as the percentage of hæmoglobin in the blood under observation. Some observers claim that there is a difference of several degrees between observations made with the operator in the position as shown in Fig. 580, and when he is to one side of the instrument. This claim, based upon difference in color appreciation of the eye in the two positions, seems a trivial one, and has not been borne out by the experiments of the writer.

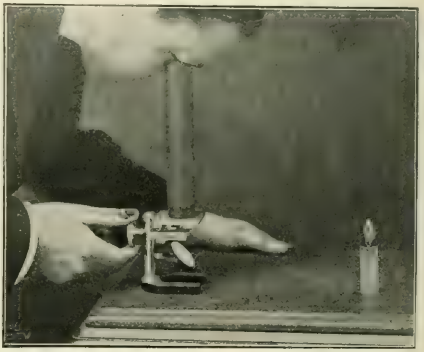
FIG. 580.—Making Observation of Percentage of Hæmoglobin with von Fleischl's Instrument. (Dark room.)

As observers differ so greatly with one another in the comparison of colors, it is better to report a percentage of hæmoglobin over a range of 5; for example, 65 to 70 per cent., 80 to 85 per cent., etc.

The quantity of hæmoglobin in grams may be estimated from this by the following simple equation:

$100 : 14 :: y : x$

100 gm. of blood contains 14 gm. of hæmoglobin.

$y =$ the reading on the von Fleischl scale.

$x =$ amount in grams of hæmoglobin in 100 of the blood under observation.

Suppose the reading to be 50, then $100 \times 14 \div 50 = 7$ gm. of hæmoglobin.

This instrument is very convenient for bedside work. Its chief objection is its expensiveness.

Professor Miescher, of Basel, has devised a means by which the blood to be used in Fleischl's instrument may be more accurately diluted. The parts of the von Fleischl-Miescher instrument are shown in the illustration (Fig. 581). The principal changes are, that instead of the capillary tube a graduated pipette is used, by means of which very accurate quantities of blood with accurate dilution may be obtained, and that wells of different depths are employed. There are a few minor changes also. We have been unable to discover any superiority in this instrument over the ordinary von Fleischl apparatus.

If the precautions already laid down by us in speaking of the von Fleischl apparatus are observed (*i.e.*, to see that all the parts correspond), the instrument will be found quite reliable. Certainly we deprecate anything which increases the cost of the already too expensive von Fleischl instrument.

Taylor's Hæmoglobinometer.—The following description and cut (Fig. 582) are from the advertisement of this instrument. I have had no experience with Taylor's hæmoglobinometer, though evidently it offers no improvement over the von Fleischl instrument. The price is $30.

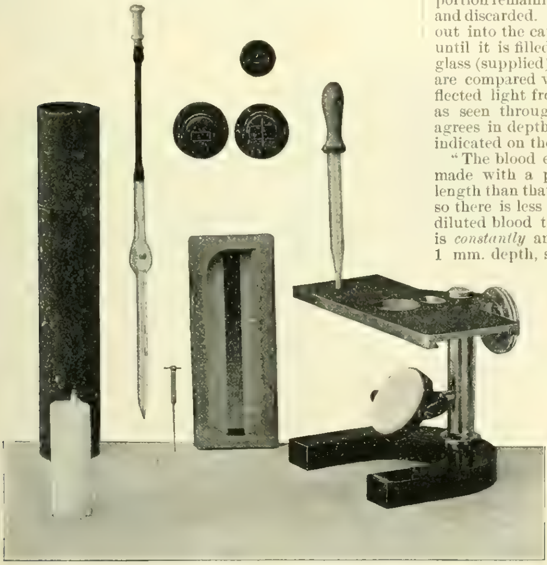

FIG. 581.—Von Fleischl-Miescher Hæmoglobinometer.

"This apparatus was suggested . . . by Dr. A. E. Taylor, of the William Pepper Clinical Laboratory of the University of Pennsylvania Hospital. It consists of a fine capillary tube and mixing bulb with bead, similar to that supplied with the Zeiss hæmacytometer, a glass wedge of gradually increasing depth of color (the same as is used with the von Fleischl hæmometer), and a rectangular glass plate with a square raised platform in the centre. This raised platform, which is cemented to the plate nearer to one side, has in its centre a circular cavity or cell of exactly 1 mm. in depth. The rectangular plate is accurately fitted in a metal frame sliding in grooves, so that the cavity with its contents can be brought successively to any part of the wedge for color comparison.

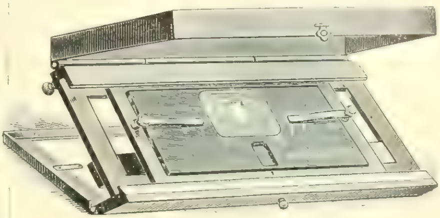

FIG. 582.—Taylor's Hæmoglobinometer.

"To use the apparatus a drop of blood is carefully drawn into the mixing tube up to the engraved mark, and distilled water is then drawn up till the bulb is entirely filled to the second engraved mark on the upper constricted end; the diluted blood is then mixed (by means of the contained bead) by shaking the bulb. The portion remaining in the capillary tube is then blown out and discarded. A part of the diluted blood is then blown out into the cavity in the platform of rectangular plate until it is filled. A ground and polished square cover glass (supplied) is placed on top and the contents of cell are compared with successive parts of the wedge by reflected light from the white background until the color, as seen through both narrow rectangular diaphragms, agrees in depth, when the percentage of hæmoglobin is indicated on the scale. . . .

"The blood examined is of *a known accurate* dilution made with a pipette, which is very much greater in length than that employed in the von Fleischl instrument, so there is less risk of inaccuracy. The quantity of the diluted blood to be compared with the Reichert wedge is *constantly* and *accurately fixed* by the use of a cell of 1 mm. depth, somewhat similar to the cell employed in the Thoma hæmacytometer. . . . The instrument can be closed and easily carried in the pocket, being about the same size as the case of the smaller Thoma hæmacytometer.

"The capillary pipette supplied allows of a dilution of 1 to 10 or 1 to 20."

Oliver's Hæmoglobinometer. — Dr. George Oliver, of London, at the same time that he devised his hæmocytometer constructed a hæmoglobinometer upon the principle of the tintometer of commerce.

As stated in describing the hæmocytometer, the term tintometer is wrongly applied to the corpuscle-counting instrument. The hæmoglobinometer of Oliver, however, does depend for its principle upon the comparison of tints, and it may therefore be called a tintometer.

The principle on which the instrument is based, namely, that every colored liquid, upon dilution or concentration, has a distinctive color curve (the same being true of colored glass) as characteristic as the specific heat of a substance (see quotation from Lovibond, p. 54), places this instrument in point of accuracy above that of Gowers, in which picrocarmine is used, and above that of von Fleischl, in which a gradation of colors is employed.

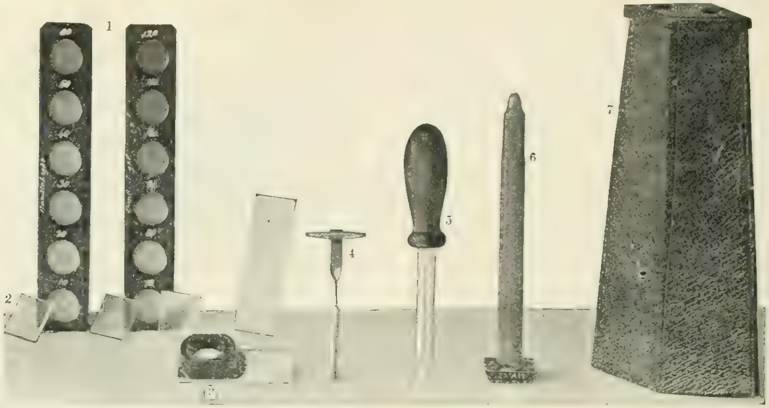

FIG. 583. Oliver's Hæmoglobinometer. 1, series of tinted glasses; 2, glasses with more delicate variation in tint to be used as riders; 3, well for reception and dilution of blood; 4, capillary tube for taking blood; 5, dropper; 6, candle and stand; 7, collapsible dark tube.

In Gowers' instrument, while the standard is fixed, yet the blood is continually changing in degree of dilution, and consequently the true color curve is destroyed. Moreover, as already stated, the standard picrocarmine changes color with age. In von Fleischl's instrument the dilution is fixed, but there is no uniformity of color in the area under observation. In Oliver's instrument there is a fixed dilution of a fixed quantity of blood compared with a fixed tint. The diluted blood and the glass that is compared with it must therefore have the same color curve.

The instrument consists of: twelve tinted glasses, in two sets of six each, mounted on white backgrounds of calcium sulphate* and ranging from 10 to 120; a capillary tube (5 cm. capacity) similar to but larger than that employed in the von Fleischl instrument; a dropper; a well with a white background of calcium sulphate; a thick cover slip (Fig. 583).

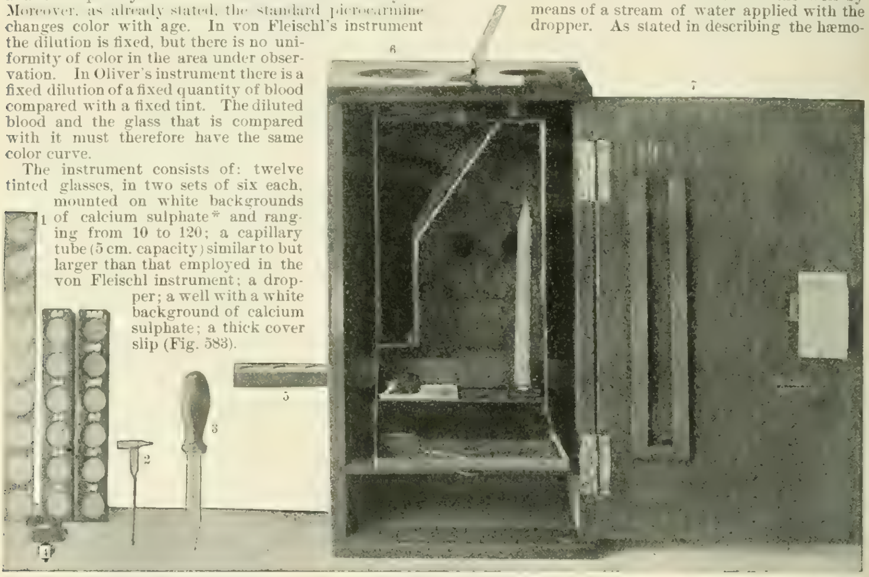

FIG. 584.—Dark Box for Estimating Percentage of Hæmoglobin by the Tintometric Method. 1, series of tinted glasses; 2, capillary tube for blood; 3, dropper; 4, well for diluted blood; 5, tinted glasses in position to one side of 4, in position, both of which can be seen and compared by looking through 6 when the door 7 is closed and the candle is lighted.

To use the instrument: Puncture is made in the usual way and the blood (quite a large drop) allowed to pass into the capillary tube, care being taken that no air spaces are formed; excess of blood is wiped away. The blood in the tube is then washed into the well by means of a stream of water applied with the dropper. As stated in describing the hæmocytometer of von Fleischl, it is unnecessary and awkward to attach the rubber tube to the capillary. The well is filled to the top, the blood and water thoroughly stirred, and the blue cover glass adjusted. A good light—preferably daylight (see Lovibond quotation, p. 54)—is obtained, and the eye screened as with the von Fleischl instrument; but the dark tube is to be held *about eight inches away* from the well, instead of upon it, as is done in using the last-named instrument. An expensive and, it would seem, unnecessary tube, called a camera tube, is supplied with the instrument.

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* This, of many substances tested, was found by Oliver to produce the least confusing influence upon the appreciation by the eye of different tints.

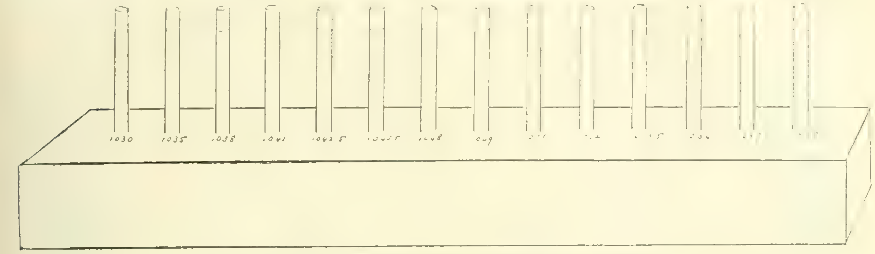

Fig. 585.—Roy's Specific-Gravity Method (Drawn by Dr. E. Dunning.)

In order to detect differences between 10 and 20, 20 and 30, etc., it is necessary to use riders each of which is equal to 1 degree.

By superimposing these riders until the exact shade of color is reached, and by then adding the number of riders employed to the next lowest figure on the scale, the percentage of hæmoglobin is ascertained. For example, 40 + 3 riders = 43 per cent. of hæmoglobin.

A candle flame may also be used for these observations; the illustration (Fig. 584) shows a box for making observations by candle flame. If such a box is not made use of, the candle should be placed about three inches from the point of observation.

The instrument has the disadvantage of being very expensive. It may be had of I. H. Smith and Co., Zürich, and of Tintometer Co., 6 Farrington Avenue, London, E. C.; price, about $30.

Dr. T. W. Tallqvist, of the Medical Clinic of the University of Helsingfors, Finland, reports in Nothnagel's "Specielle Pathologie und Therapie," Bd. viii., Th. i., Heft i., p. 10, under "Die Anæmie," by Ehrlich and Lazarus, a method for quick estimation of the amount of hæmoglobin by color comparison. By means of a carefully prepared table of colors representing known percentages of hæmoglobin, he compares the blood under examination received upon a piece of filter paper.

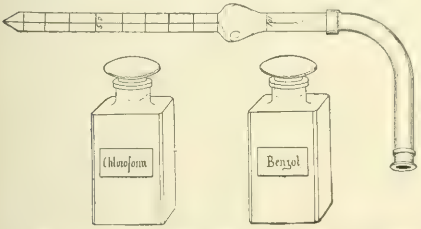

Fig. 586.—Reagents and Pipette Used in Hammerschlag's Method. (Drawn by Dr. E. Dunning.)

By aid of the von Fleischl-Miescher hæmoglobinometer Tallqvist has tested this method and finds ten per cent. the degree of error.

Dr. Arthur Dare has lately devised an instrument for estimating hæmoglobin without dilution of the blood. The instrument is somewhat on the plan of the Henocque hæmatoscope, but is much simpler and cheaper.

3. Specific-Gravity Methods.—It having been shown (by Siegel and Schmaltz) that the specific gravity of blood varies with the amount of hæmoglobin contained, these methods of estimating hæmoglobin have been placed among the important clinical tests.

A number of methods have been devised, the most important of which are those of Roy and Hammerschlag. These two methods have for their principle the comparison of blood with heavier and lighter fluids of known specific gravity and such as are non-miscible with blood.

Roy, in his method, employs glycerin and water, fluids of widely different specific gravity. A series of test tubes, as shown in Fig. 585, 4 cm. in diameter and having a capacity of from 80 to 100 c.c., are filled with the two fluids, and the specific gravity of each is determined and marked. Blood is obtained in a pipette or capillary by the usual way. A drop is blown into each test tube, *after the pipette has been submerged in the liquid*, and when that tube is reached in which the blood neither floats on the surface nor sinks to the bottom, the specific gravity of the liquid contained in that tube is read off.

Hammerschlag's method, which is clinically the more applicable, makes use of only one tube. In this method benzol and chloroform (Fig. 586) are the liquids employed, which, as before, differ widely in specific gravity and are freely miscible. The blood is introduced as in Roy's method, and the chloroform or the benzol is added until the blood floats in the mixture. The specific gravity of the mixture is then ascertained, which will also be that of the drop of blood.

Fig. 587. Specific-Gravity Method for Estimating Percentage of Hæmoglobin. Blowing drop of blood from capillary tube into receiver containing benzol and chloroform.

Dr. Scott, the writer's assistant, working in our laboratory, offers the following comparative observations on the different methods of hæmoglobin estimation:

Comparison between the Gowers and von Fleischl Instruments and the Specific Gravity Methods for Hæmoglobin Estimation.—In the accompanying tables von Fleischl's and Gowers' instruments and Hammerschlag's specific-gravity method were used. In these experiments the utmost care was taken to fulfil every requirement in the technique of each method. As a description of von Fleischl's and Gowers' instruments, and of their methods of use, have been given in another part of this article, we

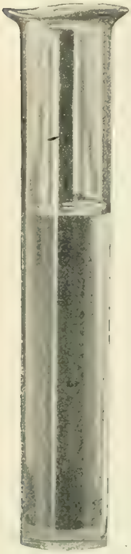

FIG. 588.—Specific-Gravity Method for Estimating Hæmoglobin. Drop of blood suspended in the fluid (chloroform and benzol).

will here describe only the specific-gravity method as employed in making these comparative observations. We have adopted Hammerschlag's method, which is a modification of Roy's, as being best suited for the general practitioner.

In this method two fluids are selected which are easily and readily miscible, and with neither of which will a drop of blood mix; further, the specific gravity of the one fluid is low, while that of the other is high.

The fluids selected are benzol (sp. gr., 0.889) and chloroform (sp. gr., 1.526), which exactly fulfil these conditions. They have the further advantage of being cheap, and the whole apparatus required is likely to be found in every physician's office. We place some of the mixture (sp. gr., 1.050–60) in a dry clean cylinder, and carefully take a drop or two of blood in a Thoma-Zeiss mixer (any capillary pipette, however, will do); we then insert the end of the tube *just below the surface of the mixture*, and blow out a drop of the blood (Fig. 587). The blood is seen as a bright red globule which does not mix with the fluid, but either sinks to the bottom, floats on the top, or remains suspended in the fluid (Fig. 588). If it sinks to the bottom this is because it is heavier than the fluid, and more chloroform must be added. If it floats on the top, more benzol is required (Fig. 589). If it remains suspended, it is of the same specific gravity as the fluid (Fig. 590). It is well to add the necessary benzol or chloroform only one drop at a time from a medicine dropper (see Fig. 589), and to stir the fluid with a glass rod to cause complete mixture. It has been found that matters are very considerably simplified, and much time and patience are saved, by having the mixture of such density that the drop of blood will sink to the bottom. It is much easier to make the globule rise by the addition of chloroform drop by drop than it is to cause it to sink by the gradual addition of benzol. Let the drop of blood remain suspended for a few minutes to see that it will neither float nor sink, and, then, when satisfied that it is stationary, ascertain the specific gravity by means of an ordinary hydrometer (see Fig. 590). By filtering the mixture of benzol and chloroform they can be used again and again.

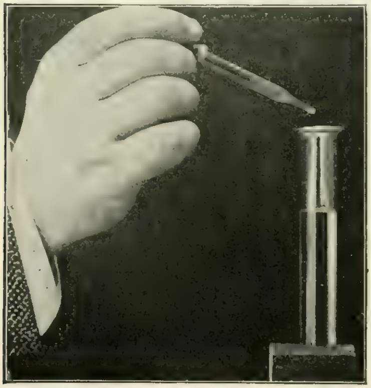

FIG. 589.—Specific-Gravity Method for Estimation of Percentage of Hæmoglobin. Adding fluids (benzol or chloroform) until drop of blood is suspended.

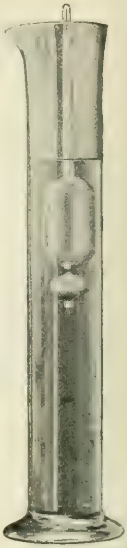

FIG. 590.—Specific-Gravity Method for Estimating Percentage of Hæmoglobin. Taking specific gravity of fluid. Drop of blood seen suspended in fluid.

The drop of blood will remain in the mixture for a considerable time without its specific gravity changing. In the illustration (Fig. 590) the drop remained suspended for forty-eight hours before the photograph was taken.

In Table I., below, a variation is to be noted between von Fleischl's and Gowers' estimates, but the variation is not constant in either direction. There is more steady agreement between those of von Fleischl and of Hammerschlag respectively; and this is more particularly seen in Table II., which gives comparative estimates of hæmoglobin of the blood from each ear of the patient. Here, too, it will be seen that the specific-gravity readings are quite constant; while the von Fleischl readings vary somewhat, and those of Gowers vary considerably.

Dr. Scott's tables show very satisfactorily how little is the variation between the specific-gravity method, which is so simple in cost, and the expensive instruments. Even with the von Fleischl instrument one prefers to report his observations over a range of five points—75 to 80 per cent., for example; while with the specific-gravity method the observations can be more precise—as in Dr. Scott's tables, where in most instances the observations are within a range of two or three points. Such reading would also include the reading with Gowers' or von Fleischl's instrument. It was for the purpose of determining the accuracy of the specific-gravity method that Dr. Scott made these observations, and our conclusion is that this method is, clinically, perfectly reliable and satisfactory.

TABLE I.

No.	Percentage of hæmoglobin according to von Fleischl's hæmoglobinometer.	Percentage of hæmoglobin according to Gowers' hæmoglobinometer.	Specific-gravity. Method of Hammerschlag.	Percentage of hæmoglobin corresponding with this specific gravity.
1	68	69	1050	65
2	71	69	1052	68–9
3	68	67	1050	65
4	63	59	1049	60
5	75	69	1055	75
6	73	69	1054	72
7	78	71	1056	80
8	76	77	1054	72
9	78	77	1056	80
10	93	89	1059	91–2
11	81	81	1056	80
12	68	67	1052	68–9
13	73	69	1054	72
14	65	68	1051	67–8
15	92	87	1059	91–2
16	64	62	1050	65
17	91	92	1059	91–2
18	53	57	1048	55
19	82	88	1057	85
20	61	55	1049	60
21	52	49	1047	51–2
22	65	66	1050	65
23	78	76	1056	80
24	81	73	1056	80

TABLE I.—*Continued.*

No.	Percentage of Hæmoglobin According to von Fleischl's Hæmoglobinometer.	Percentage of Hæmoglobin According to Gowers' Hæmoglobinometer.	Specific-gravity Method of Hammerschlag.	Percentage of Hæmoglobin Corresponding with This Specific Gravity.
25	78	77	1057	85
26	77	73	1056	80
27	96	91	1060	95
28	62	69	1049	60
29	85	66	1057	85
30	58	57	1050	65
31	71	69	1053	70
32	68	68	1052	68-9
33	86	79	1058	88-9
34	82	83	1057	85
35	81	83	1057	85
36	78	73	1056	80
37	80	74	1057	85
38	80	78	1056	80
39	87	83	1058	88-9
40	90	90	1059	91-2
41	75	72	1055	75
42	68	67	1052	68-9
43	81	83	1056	80
44	81	84	1056	80
45	78	76	1055	75
46	88	88	1058	88 9
47	86	83	1057	85
48	78	72	1056	80
49	85	87	1057	85
50	82	80	1056	80

TABLE II.

No.	Left Ear.			Right Ear.		
	Von Fleischl.	Gowers	Specific Gravity.	Von Fleischl.	Gowers.	Specific Gravity.
1	87	83	1058	88	84	1058
2	90	90	1059	90	90	1059
3	75	72	1055	75	73	1055
4	68	67	1052	68	67	1052
5	81	83	1056	81	83	1056
6	81	84	1056	81	83	1056
7	78	76	1055	78	76	1055
8	88	88	1058	88	86	1058
9	86	83	1057	86	82	1057
10	78	72	1056	78	74	1055
11	85	87	1057	85	86	1057
12	82	80	1056	82	80	1056

Color Index.—This refers to the relation between the number of red cells and the percentage of hæmoglobin.

Suppose the red blood corpuscle count to be 5,000,000; this being the normal, we may designate it as 100; then:

5,000,000 red blood corpuscles = 100
4,500,000 " " " = 90
4,000,000 " " " = 80
3,500,000 " " " = 70
3,000,000 " " " = 60, etc.

Suppose the hæmoglobin to be 100 per cent. This is the normal. Then $\frac{100}{100} = 1$, represents the normal state of the blood; 1 is the normal color index.

A general formula by which the color index may be arrived at would be the following:

$\frac{A}{B}$= color index, in which A = percentage of hæmoglobin and B the number of red blood corpuscles reduced to terms of 100.

Examples: Chlorosis, $\frac{50}{100} = 0.5$ color index. Pernicious anæmia, $\frac{40}{50} = 0.8$ color index. Secondary anæmia, $\frac{60}{80} = 0.75$ color index.

Chlorosis, it will be seen, has the lowest index, pernicious anæmia the highest; that is, in pernicious anæmia each corpuscle is carrying more hæmoglobin than is the case in chlorosis. This is the *value globulaire* of French writers.

The Anæmias—detected by the use of the blood counting and hæmoglobin-estimating apparatus. (For complete table, see page 69.)

- Anæmia..
  - Primary .. Chlorosis, Pernicious.
  - Secondary
    - Hemorrhage: Purpura, Menses, Hemorrhoids, etc.
    - Poisons .... Arsenic, Lead, Mercury, Silver, etc.
    - Diseases .... Wasting diseases, Malaria, Inanition, Tuberculosis, Chronic suppuration, Chronic Bright's, Pyrexia, etc.

Terms: Oligæmia—ὀλιγος, too little, αιμα, blood—too little blood. Oligocythæmia—ὀλιγος, too few, κυτος, circle, αἷμα, blood—too few blood cells. Oligochromæmia—ὀλιγος, too little, χρῶμη, coloring matter, αἵμα, blood—too little coloring matter. Leukæmia,—λευκος, white, αἷμα, blood—white blood. Leucocytosis—λευκος white, κυτος, circle, οσις, full of—full of white corpuscles.

IV. BLOOD-CLOTTING.

The fact that normal blood requires a fixed time for clotting, and that in certain diseases this time varies, makes the phenomenon of blood-clotting of clinical value. However, in the description of apparatus and technique employed in the clinical examination of blood, the discussion of the various causes, etc., producing this phenomenon can have no place. Text-books on physiology and the article on *Coagulation* should be consulted for information on this subject. Therefore, beyond describing the apparatus employed and mentioning the diseases in which variations in the time required for clotting occur, the subject will receive no further consideration.

Two methods for determining the rate of coagulation may be employed:

1. The rough test, in which two drops of blood, as nearly equal in size as possible—one from the case under observation and one from a normal individual—are compared as to clotting time.

2. The more accurate test, in which Wright's coagulometer tubes are employed.

1. *The Rough Test.*—A drop of blood from the case under observation is received on a glass slide, and simultaneously a drop as nearly as possible of the same size as that from the suspected case is taken from a normal case and placed upon another glass slide. The time at which the operation is begun is noted. The two slides are placed side by side, and by means of a pin touching the edge of the drop, the stage of the process of clotting is ascertained from time to time. The moment of complete clotting is determined when the pin, being drawn from within outward, no longer leaves a small projection at the periphery of the drop. The time is noted and compared with that of the normal blood. This is a test by comparison. The actual time should not be taken.

2. *The More Accurate Test.*—In this test, equal quantities of blood are taken by means of accurately graduated tubes. These tubes are blown through, one after another, until that tube is reached which cannot be blown out, and in which, therefore, the contained blood has clotted. The time from the taking of the blood to the moment when the blood has clotted is noted, and this is termed the "coagulation time."

Wright's coagulometer tubes are of two kinds (Fig. 591): 1. Those for testing the coagulation time of the blood. 2. Those for testing the coagulation power of certain substances.

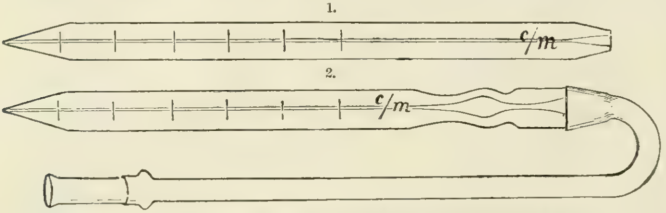

FIG. 591. -Wright's Coagulometer Tubes. 1, Ordinary tube; 2, tube with mixing chamber.

1. *Those for Testing the Coagulation Time of Blood.*—These tubes have a centimetre scale, 6 cm. in all, and are shaped as seen in Fig. 591. There are eight such tubes in a set. There is also a round tin receiver, surrounded by a jacket, in which there are nine pockets—eight for the reception of the tubes, the ninth being for the reception of a thermometer (Fig. 592). This part of the apparatus is for the purpose of heating the tubes to blood heat before use by placing heated water in the centre tin. This is not essential, as the normal blood is found to be coagulated in the same time without previous heating of the tubes as when such heating is carried out. If heating is resorted to, the thermometer should register 18.5 cm. (half blood heat), or, if clotting is very slow, 37.0 cm. (blood heat).

The test is made as follows: The tubes, as seen in illustration (Fig. 591), are laid out (if the heating tin is not used) on a sheet of white paper on a table at the bedside. An open watch is also laid upon the table. A fairly large puncture is made in the skin in the usual way. A rubber tube with mouthpiece (similar to that used with the Thoma-Zeiss mixer) is attached to the first tube and blood is drawn up to the fifth division, the time by the watch being noted. Taking the point of the tube away from the blood drop, the column of blood is drawn up to the sixth marking, thus removing the end of the column from the immediate influence of the air. This tube is laid upon the white paper, and the moment at which the observation is begun noted down. In about half a minute the second tube is treated in the same way, in another half-minute the third, and so on for the whole set. After the lapse of about one minute the first tube is gently blown through; if the blood is still liquid the second tube is blown through; and so on until a tube is reached from which the blood cannot be blown. The time at which this condition is observed is at once noted and compared with the time, as marked on the paper, at which the observation of the blood in that tube was begun. The difference between the two numbers constitutes the time required for this specimen of blood to clot, and is therefore the "coagulation time." *The time is taken from the moment the blood is drawn into the tube to that at which it cannot be blown from the tube.*

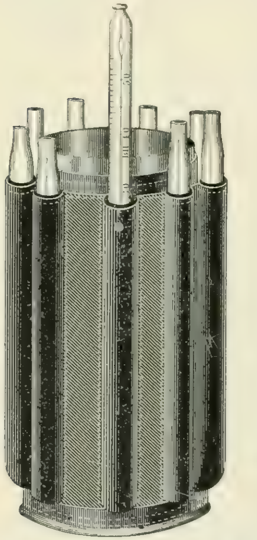

FIG. 592.–Case and Warm Chamber for Wright's Coagulometer Tubes. Chamber for warm water in centre surrounded by leather jacket containing tubes and thermometer.

2. In using the instrument to determine the coagulation power of certain substances, the tubes with the mixing space are employed (see illustration, Fig. 591, 2). The substance to be tested is drawn up to one of the divisions on the tube, say the second. Blood is then also drawn up, and the blood and substance to be tested are thoroughly mixed in the mixing space. Unmixed blood is now drawn into another tube, and the different coagulation times for the two tubes are noted. Prof. Wright exhibited at the Paris Congress, August, 1900, an improvement upon this instrument. The author has obtained the first of these improved instruments placed upon the market, but has not as yet tested it sufficiently to warrant him in expressing an opinion.

Cleansing the Tubes.—This is one of the annoyances of the Wright tubes, for unless cleaned *at once* the tubes become hopelessly clogged. It is well, therefore, to have an attendant draw clear water into each tube the moment the observation has been made upon that tube. It is evident that as the observer is occupied with his observations, those tubes already tested, and containing traces of blood, will become dried out and clogged. A wire should be passed down the tubes to break up the clotted blood.

When *all trace* of blood has been removed, and *not till then*, 95 per cent. alcohol should first be drawn through the tubes, and afterward ether. The tubes will then be ready for use again. The importance of prompt action in the matter of cleaning the tubes cannot be too emphatically stated; disregard of this promptness will render the tubes useless.*

COMPARATIVE TIME OF COAGULATION IN CERTAIN DISEASES.

(*Normal, two to three minutes.*)

Coagulation Rapid.

Malignant disease:
  inflammation or sloughing in progress.
Pneumonia.
Hæmoglobinæmia:
  in severe grade of malaria;
  in severe grade of septicæmia;
  in yellow fever;
  in typhus fever;
  in burns.
Poisons:
  snake poisoning;
  chlorate of potassium;
  antipyrin and antifebrin;
  hydrocyanic acid;
  phenacetin;
  phosphorus;
  carbonic acid;
  illuminating gas.

Coagulation Delayed.

Malignant disease:
  uncomplicated.

Jaundice (important in operation for gall stones, as one of the most common complications causing fatal results is postoperative hemorrhage due to reduced coagulability of the blood.
Obscure conditions associated with frequent attacks of epistaxis:
  hæmophilia;
  scurvy;
  erythema multiforme;
  pernicious anæmia;
  anæmia, delayed in accordance with severity;
  purpura hæmorrhagica.

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* The Wright apparatus may be had of Alfred E. Dean, 73 Hatton Garden, London, E. C., for £2 5s; the improved instrument of T. Hawksley, 357 Oxford Street, London, for £1 15s.

The coagulation time may be increased by·

1. Inhalation of carbonic acid gas.
2. Ingestion of calcium chloride.
3. The gelatin treatment for aneurism. (*a*) Lancereaux's method: 4–5 gm. white gelatin dissolved in 200 c.c. of 0.7 per cent. sodium chloride solution and sterilized at 120° C. (*b*) Futcher's method: 250 c.c. of one per-cent. gelatin solution in normal salt solution (*Journal of American Medical Association*, January 27, 1900).

DETECTION OF BLOOD WHEN IN SMALL QUANTITIES.—For full information upon the more complicated apparatus and technique (spectroscopic and chemical) employed in the detection of blood for medico-legal purposes, the reader is referred to the article on *Blood Stains.*

A simple clinical test is the following: Allow a few drops of the fluid supposed to contain blood (urine, gastric contents, etc.) to dry upon a glass slide. Add to the margin of the dried fluid a few grains of common salt. Now from a pipette allow a drop or two of glacial acetic acid to attack the salt and dried fluid. Gently heat the slide until the acid has dried entirely; examine with low power. If blood is present crystals of hæmin will have formed. Hæmin is a derivative of hæmatin (or hydrochlorate of hæmatin) which is thus produced. If no blood be present no crystals will be formed.

VI. STAINING OF DRIED SPECIMENS OF BLOOD.

Through the labors of Ehrlich we have learned that the blood corpuscles react variously to the aniline dyes: that some of the white corpuscles contain specific granules which in health react to these dyes in one way, while in disease these same granules react in a different way. So constant is this peculiarity that an entire system of diagnosis has become possible simply through the process of staining the blood.

As this branch of the study of the blood depends entirely upon the peculiar reaction, not of the corpuscles as a whole, but of certain parts of the corpuscles, our technique must be even more delicate than in any system of diagnosis already described.

There are two methods of preparing the blood for staining: (1) The slide method. (2) The cover-slip method.

(1) *The Slide Method.*—Puncture is made in the skin in the usual way. A drop of blood is received at one end of an absolutely clean glass slide. The edge of another glass slide is dipped into the drop of blood and drawn gently along the surface of the first slide. This produces a large and fairly thin smear of blood. The objections to this method are: (*a*) Too large a smear; (*b*) smear not thin enough; (*c*) unequal spread, thicker in one place than in another; (*d*) apt to mutilate the corpuscles.

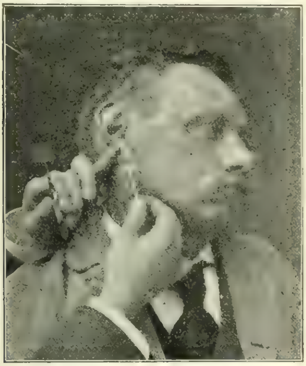

FIG. 593.—Method of Taking Dried Specimen of Blood. First step.

(2) *The Cover-Slip Method.*—Several No. 1, ½ inch, square Bausch and Lomb cover slips are *thoroughly* cleaned with alcohol and ether. Every trace of dust and cloudiness must be removed. These cover slips are placed on a sheet of white paper on a table near the patient. It is hardly necessary to state that they should be held *by the edges* and not by the flat surface—that portion which comes in contact with the blood, and which, therefore, we should take every precaution to keep clean. A lighted spirit lamp should also be at hand. The point of puncture is cleaned with alcohol and ether; this is more important in taking the dried specimen than in taking the fresh specimen. One of the cleaned cover slips is placed in the clamp forceps, as shown in Fig. 540, No. 4 *b*, p. 38, and the forceps thus armed laid upon a table near at hand. Puncture is made in the usual way. After removing the first drop, the clamp forceps holding the cover slip is held in the left hand, and the second drop is received upon a cover slip held by the open forceps (see Fig. 540, No. 5, p. 38) in the right hand. This is the first step, and is shown in Fig. 593.

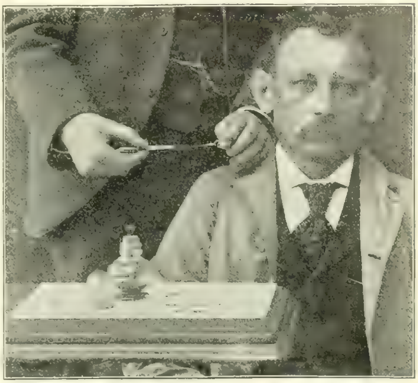

FIG. 594. Method of Taking Dried Specimen of Blood. Second and third steps.

The cover slip with the drop of blood is *immediately* transferred to the cover slip held in the clamp forceps, as follows: The edge of the cover slip upon which is the drop of blood and which is held in the open forceps is placed against the end of the limb of the clamp forceps holding the other cover slip. Thus held, the cover slip is slowly lowered until the drop of blood almost touches the undermost cover slip. The right hand forceps is then opened and withdrawn, which allows the cover slips to come together with the blood between and spreading equally in all directions. This is the second step, and is shown in Fig. 594. If these steps have been carefully carried out, the blood specimen should appear as in the illustration (see Plate XIII., Fig 1).

Directly the blood is no longer seen to spread the two slips are drawn apart, in such a manner, however, that they shall at all times be *parallel with each other.* This drawing apart must be *quickly done*, for if performed too slowly it will be found very difficult to keep the slips parallel with each other—an essential point,—the upper slip rising at the last and making a great clump of blood on the lower slip

In order to act thus quickly, and to be sure of the slips coming away at one pull, it is well to take an additional hold upon the clamp forceps far down the limbs, near to the cover slip. This is the third step, and is shown in Fig. 594. The cover slips thus separated are now held from eighteen inches to two feet above the spirit lamp until the blood is quite dry. This is the fourth and last step, and is shown in Fig. 595.

It is recommended by some hæmatologists to use the thumb and forefinger in drawing the upper slip away, rather than to use the open forceps. When this plan is followed the corners of the cover slips should not exactly correspond, but one cover slip should be allowed to project beyond the other, so as to offer something to hold on to. As it is better not to touch the cover slip except with the forceps, and as the moisture of the skin readily adheres to the glass and ruins the blood specimen, the forceps method should certainly be preferred.

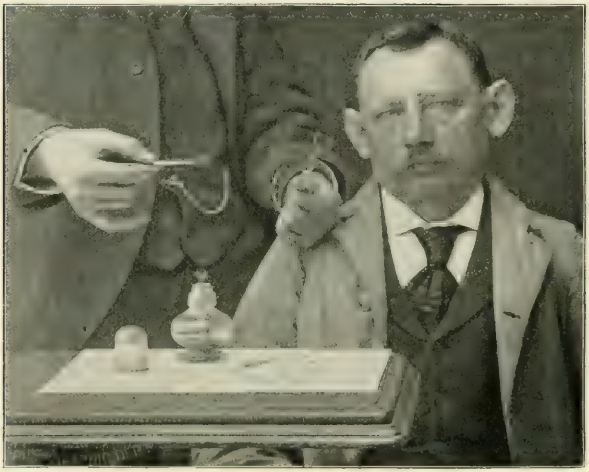

FIG. 595.—Method of Taking Dried Specimen of Blood. Fourth step.

Thayer mentions that flies attack the dried specimens, eating holes in them. While this is undoubtedly true in some cases, yet the holes which one sees in dried specimens are more commonly caused by allowing the blood to dry in the air instead of using a spirit lamp. The writer has seen these holes in specimens taken in winter.

The prepared specimens may now be placed in a labelled pill box and kept indefinitely. The method of preparation here given permits of the preserving of specimens for a number of years, to be used for class purposes; or of sending them, packed in a little cotton, by mail to an expert. By learning this simple technique, therefore, a physician engaged in practice in a section of the country removed from laboratory opportunities, or one occupied in military duties, may take specimens and send them to a laboratory for examination.

The painful mistakes made in establishing the differential diagnosis between typhoid and malaria among the American soldiers in the late Spanish war might have been avoided, and many lives saved, had the microscope been given more place and some of the simple methods above described been carried out. The indiscriminate administration of quinine, while perhaps benefiting many malarial cases, must have produced injurious effects upon the ulcerated intestine.

Before proceeding to the work of staining it is necessary to "fix" the contents of the corpuscles so that they shall not become dissolved; and this is called fixation. A number of methods have been employed, which may be divided into fixation (1) by heat; (2) by fluids; (3) by vapors.

(1) *Fixation by Heat.*—(*a*) Ehrlich's copper-bar method. (1878). A spear point made of copper and about eighteen inches in length is placed upon a support, as shown in cut (Fig. 596). A Bunsen burner is so located that the flame will strike the extreme point of the bar. The flame of an ordinary Bunsen burner, if applied to the extreme tip of a bar of this size, will be able to heat only a certain amount of the bar to a certain degree of heat; beyond which the temperature will not rise, no matter how long the bar is subjected to the flame. In other words, the flame has a limited heating power. This would at once be appreciated if we should attempt to heat with the ordinary Bunsen burner a copper bar five or ten feet long. We should not be surprised to find the far end of the bar cold, no matter how long the copper may have been submitted to the flame. We should realize that the little flame, with its limited heating power, could not heat so large a bar. The heating power of an ordinary Bunsen burner does not extend, on a metal bar, beyond the distance of eighteen inches. What we wish to obtain by this heating procedure is the fixed boiling line on the bar. This we accomplish by placing drops of water upon the surface of the bar, about twenty minutes after it has been subjected to the flame; and directly the point farthest from the apex of the bar at which a drop of water boils away is found, we draw a chalk line across the bar at that point. This marks the temporary boiling line. After the lapse of a few minutes we put another drop of water just beyond the line; if the boiling point has extended the drop will boil away, and we then draw a second line at the new point and still farther from the apex. This procedure is repeated until a point is reached at which the water does not boil away, when we know that the limit of the heating power of the flame has been located. Once the permanent boiling line is thus located, no matter how long the flame is allowed to attack the apex of the bar, the line will never extend any farther from the apex. The confirmation of the fact that this line has been reached is

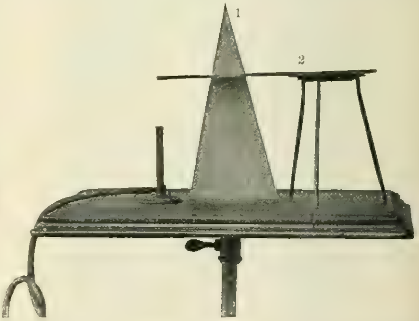

FIG. 596.—Ehrlich's Copper-Bar Method of Fixation of Blood Specimens by Heat. 1. Bar placed in upright position to show shape; 2, bar in place with Bunsen burner at tip.

afforded when a drop of water boils away almost at once on the apex side of the line, but remains until slowly dried off on that side of the line away from the apex. This, then, is the line we seek, and it is called the fixed boiling point or line. The blood specimens, as above prepared, are now laid *blood side up* either upon this line or directly to the boiling side of it. If the boiling line has been accurately located, it is, in the writer's experience, rather severe treatment to place the specimens blood side down on this line, as recommended by Cabot ("Clinical Examination of the Blood," third edition, p. 44). Specimens so placed are allowed to remain from forty minutes to an hour, except in cases of pernicious anæmia or of grave secondary anæmia, when a much shorter time—perhaps only twenty minutes—is sufficient. This is not satisfactory for malaria specimens. One should be careful not to allow draughts to influence the direction of the flame, as in this way the bar is chilled and the boiling point thereby altered for a period of several minutes. Ehrlich's copper-bar method is a good one, in the thoroughly equipped laboratory, for specimens prepared for class purposes; but it is tedious and calls for much watching, and has been replaced by quicker and simpler methods which seem, so far as one can at present judge, equally good.

(*b*) A quick heat method, and one applicable to office work, is that by means of the spirit lamp. The specimens, taken as above described, are simply held about two feet above the flame until the blood is thoroughly dried; or the cover slips may be heated to 60° or 70° C. (a temperature which can be borne by the skin) before taking specimens. This serves for immediate staining and examination; but for specimens which are to be kept for a long time, or in which accurate differential examination is desired, it will be found unsatisfactory.

(*c*) Another fairly quick heat method is that by means of the thermostat, brought gradually to a temperature of 150° C. and kept at this degree of heat for from forty minutes to an hour. This is as satisfactory as the copper-bar method, but not as readily carried out.

(*d*) Another simple means is to make use of the top of a steam register, upon which the specimens are allowed to remain for from forty minutes to an hour. This is a very good and convenient method. Care must be taken that no moisture shall be on the metal.

(2) *Fixation by Fluids.*—(*a*) Of these, Nikiforov's method is the best. It calls for equal parts of absolute alcohol and ether. The specimens are immersed in this liquid for from two to four hours. This, next to the formalin method given below, is the best for malarial specimens. For quick work fairly good results may be obtained from an immersion lasting twenty minutes.

(*b*) Dr. G. A. Tuttle has lately devised a method which is described by Dr. Fred P. Solley, in the reports of the Pathological Department of the Presbyterian Hospital, New York City. It was kindly brought to my attention by Dr. W. G. Thompson. The following is taken from those reports:

"Experiments were made by Dr. G. A. Tuttle with chromic acid, and after trials of different strengths for varying periods of time he found that a two-per cent. solution poured on the film and allowed to remain for exactly thirty seconds gave uniformly good results, both red and white cells taking up their special stains clearly and surely. The nuclei and granules of the leucocytes stain quite as sharply as in the best specimens fixed by heat—while the protoplasm of the mononuclear lymphocytes is usually better stained than by the latter method.

"By this method, then, the whole process of preparing the specimens for examination is reduced to five or six minutes, and when the films are evenly and thinly spread the preparations are certain to be available for accurate differential computation. The red cells occasionally show defects as a result of the action of the acid; but this usually means that the solution has been left on too long, or that the films were unevenly spread. Indeed, the spreading of the films is of the utmost importance in securing satisfactory results by any method. . . . The two-per-cent. chromic acid solution is spread from a dropper over the film, the cover glass being held in a staining forceps. After thirty seconds the acid is thoroughly washed off and the excess of water removed by tapping a corner of the square on filter paper. The stain is then poured over the film in the same manner, and washed off quickly after three minutes. The specimen may then be dried between layers of filter paper and is ready to be mounted in balsam.

"By employing this method a complete blood examination may be carried out in a little over an hour at the bedside of the patient, often affording valuable information in cases in which the desirability of surgical intervention is in question."

This method has proved most satisfactory in my hands.

(*c*) Bichloride of mercury and Müller's fluid (formula, see p. 48, footnote) may be used, but the results are uncertain.

(*d*) Formalin method. Five drops of ten-per-cent. formalin solution are mixed with 10 c.c. of 95 per cent. alcohol. The cover slips are immersed in this for thirty seconds.

Futcher and Lazear report this as a most satisfactory method for malarial blood. The writer has found that when using the Ehrlich eosin hæmatoxylon stain this is a thoroughly reliable fixing method. Futcher and Lazear's statement as to its value for malarial specimens is, in the writer's opinion, to be indorsed.

(3) *Fixation by Vapors.*—In this method cotton soaked in two-per-cent. formalin is kept at the bottom of a wide-mouthed bottle. The specimens are subjected to the vapor from this, with the cork in the bottle, for from fifteen to thirty seconds. This is a good office-table and classroom method. During one winter my classes at the Cornell University Medical College prepared all their blood specimens by this method. While quickly obtained, the stains were not permanent, so that in a few months they had almost wholly faded out.

Blood Stains.

The following is not an exhaustive article upon blood staining; it treats of this subject only in so far as it is part of the apparatus used in the clinical examination of the blood. So much has lately been accomplished in the differential staining of the malarial parasite that this part of the subject of blood staining will be treated of under other heads (*Histological Technique, Malaria,* etc.).

In the process of distillation of coal gas from bituminous coal, for ordinary lighting purposes, there condenses upon the pipes a "thick, black, opaque, viscid liquid" which is known as coal tar. From this coal tar have been separated great numbers of useful products, such as paraffin, naphtha, benzol, creosote, carbolic acid, pitch, etc. When benzol is acted on by nitric acid, nitrobenzol is formed, and this, when treated with nascent hydrogen, produces aniline, which is an oily liquid, aniline oil occurring as a by-product of the process. This aniline is a chemical base and unites with acids to form salts. These salts are of a great variety of most beautiful colors—violet, green, purple, etc.—and are the origin of our valuable stains in microscopic work. Benzol being the source commonly employed in the preparation of the aniline dyes for commerce, this would make these dyes apparently by-products of coal tar. Aniline, however, is a direct product, but in too small quantities to make it profitable to separate it. The word anil comes from the name of a plant from which indigo is made; the word signifies purple, and is applied to this product of coal tar as purple is one of the most striking colors produced by the combination of aniline with an acid.

The stains used in microscopic work are manufactured by Grübler in Germany and sold in powder form. From these, various strengths of stain may be made. The system by which these powders are classified is at times confusing. It is to be regretted that the names are selected so as purposely to convey no information beyond that of enabling the compounder to refer to his records and there learn the secret process which produced the stain. So no further explanation can be given of this classification. Many of these names, as tropaeolin ōō and orange "G," were given by the commercial compounders and have been adopted by Grübler, who confines himself to the preparation of stains for scientific purposes. Eosin is from the Greek word meaning the dawn. Methyl blue and methylene blue differ the one from the other in that the former, mixed with sodium hydrate, changes color to a reddish brown, the latter to violet. Methyl blue is the stain usually employed in blood work.

The stains are grouped into two general classes—acid and basic. These terms do not indicate a litmus reaction, and are therefore not to be taken in the strict chemical sense. The stains are for the most part neutral salts, that is, made up of a base and an acid, but neither acid nor basic in reaction. Now if the acid part of a salt is the staining element in the salt, the stain is called an acid stain. Example: ammonium picrate, which is a salt made up of ammonia, *the base*, and picric acid, *the acid*. Picric acid is the element in the salt which stains; hence the name *acid stain*. Another stain is rosanilin acetate—rosanilin is *the base* and acetic acid is *the acid*. The base in this salt is the staining element, and hence the name *basic stain*. The term *neutral stain* refers rather to a peculiarity of the tissue than to the stain.

According to this grouping of the stains the tissues are also classified. Those tissues which stain with an acid stain only are called eosinophilic; those which stain with a basic stain only are called basophilic, and those requiring both an acid and a basic stain are called neutrophilic. Tissues which consistently stain with an acid stain were termed by Ehrlich eosinophilic, because eosin was the most striking stain of the acid group. Now that we have all our stains clearly classified, however, it is better to adopt a term referring to the entire group rather than to a single stain in the group. Oxyphilic (ὀξύς, acid; φιλέω, I take to) is therefore a better word.

THE STAINS.

(This list contains only a few of the more common stains.)

Acid.	Basic.
Eosin,	Rosanilin acetate,
Fuchsin (acid),	Fuchsin (basic),
Orange "G,"	Saffranin,
Picric acid,	Methyl blue,
Aurantia,	Methyl violet,
Indulin,	Methyl green, etc.
Nigrosin,	
Tropaeolin ōō, etc.	

The *Tissues*, according to the explanation just given, are grouped by Ehrlich as follows:

1. Oxyphilic (ὀξύς, acid; φιλέω, I take to), synonymous with eosinophilic (acidophilic is a hybrid, and should therefore be discarded), refers to tissues taking only acid stains. The Greek letter "α" is used to designate oxyphilic granules. Example: eosinophiles of human blood.

2. Amphiphilic (ἀμφί, both)—refers to those tissues staining equally well with either an acid or a basic stain. Example: the bone marrow of rabbits. There are no amphiphilic granules in human blood. The Greek letter "β" is used to designate amphiphilic granules.

3. Basophilic refers to tissues taking only basic stains. Example: Mastzellen. The Greek letter "γ" is used to designate basophilic granules.

4. Neutrophilic refers to tissues requiring both an acid and a basic stain. Example: polynuclear leucocytes. The Greek letter "ε" is used to designate neutrophilic granules. (The word neutrophilic is a hybrid—neutron, neither, and φιλέω, to take to. Oudeterophilic (οὐδέτερος, neither), would be more correct but not as simple, perhaps, as the present word.)

In order to demonstrate these staining reactions of the various blood corpuscles and their granules, the stains should be each in turn applied to specimens of blood; then the specimens should be examined, and those parts which take the stain should be noted.

For example, subject a specimen of blood to an acid stain—eosin. Result: Red cells stained; eosinophile granules stained; granules of polynuclear leucocytes very faintly tinged; *all else unstained.*

Subject a specimen of blood to a basic stain—methyl blue. Result: Nuclei of all leucocytes stained; granules of polynuclear leucocytes very faintly tinged; *all else unstained.*

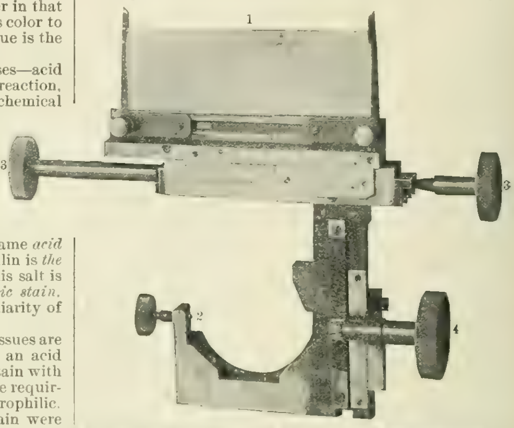

FIG. 597. -Mechanical Stage. 1, Slide in place; 2, space and screw for reception of and fastening to upright of microscope; 3, screw for lateral motion of slide; 4, screw for forward and back motion of slide.

Subject a specimen of blood to a neutral stain—eosin and methyl blue. Result: Red cells stained red; eosinophile granules stained red; nuclei of leucocytes stained blue; granules of leucocytes stained reddish blue.

The blood thus prepared is now examined and the percentage of normal cells, peculiarities of staining, and cells not normally in peripheral circulation are noted. In order to examine these fields accurately and not to recount the cells we employ the mechanical stage (Fig. 597). This is so constructed as to enable one to move the specimen a microscopic distance at a time from side to side, up and down, and across diagonally. It is moreover supplied with a register by means of which the observer may take note of his whereabouts in the field, so that having moved away from the field, he may return to it again by causing the figures upon the register to stand according to the position previously noted. In this way corpuscles may be restudied and at the same time the whole specimen thoroughly examined.

When the blood has been fixed as already described it is then subjected to the stains for varying lengths of time. The following are a few of the stains and formulæ employed in blood work:

1. Eosin: 0.5-per-cent. alcohol solution; one-half to one minute. Methyl blue—saturated aqueous solution; one-half to one minute.

2. Ehrlich's triple stain:

1	Acid fuchsin.............	3.5	1	3	4
	Aquæ......................	2.0			
2	Orange "G"...............	6.0	2		
	Methyl green.............	6.5			
	Aquæ.....................	10.0			
	Absolute alcohol.........	5.0			

The brackets show the order in which ingredients should be mixed in preparing the stain.

NOTE.—The sero-diagnosis test for typhoid fever is not included in this article, being considered under the head of *Typhoid Fever*.

TABLE SHOWING THE SOURCE, APPEARANCE, STAINING REACTION, GREEK LETTER EXPRESSING STAIN, AND THE NUMERICAL VALUE OF EVERY CELL FOUND IN THE PERIPHERAL CIRCULATION UNDER NORMAL OR PATHOLOGICAL CIRCUMSTANCES.

Name according to source.		Name according to appearance.	Name according to stain.		Name according to Greek letter expressing stain.	Numerical value of each cell.	
			Protoplasm.	Nucleus.			
Non-granular.	1.	Erythrocytes. Red cell	Oxyphilic		(α)	5,000,000 to cubic millimetre.	
	2.	Normoblast (Nucleated red cells)	"	Basophilic	(α)	Found normally in bone marrow only. In peripherial circulation in pernicious and grave secondary anæmia.	
	3.	Gigantoblast or megaloblast (Nucleated red cells)	"	"	(α)		
	4.	Plates	Basophilic		(γ)	300,000 to cubic millimetre.	
			Granules.	Nucleus.			
	5. Lymphocyte	Leucocytes. Small mononuclear	Neutrophilic (Sometimes basophilic granules at periphery.)	Basophilic	(ε) (δ)	6,000 to 10,000 in c.mm.	20-30 per cent.
	6. "	Large "	Neutrophilic	"	(ε)		2-3 "
	7. "	Transitional "	" (Basophilic in leukæmia)	"	(ε)		2-3 "
	8.	Polynuclear	" (Basophilic in leukæmia)	"	(ε)		60-70 "
	9.	Coarse granular (Eosinophile)	Oxyphilic (Eosinophilic)	"	(α)		2-3 "
	10. Myelocyte		Neutrophilic	"	(ε)	Found in bone marrow only. In peripheral circulation in splenomedullary leukæmia.	
	11. Mastcell		Basophilic (Requires dahlia to stain.)	"	(γ)	¼ of 1 per cent. (Virchow). Increased in leukæmia.	
	12. Eosinophilic myelocyte		Oxyphilic	"	(α)	Found in bone marrow only. In peripheral circulation in splenomedullary leukæmia.	

NOTE.—The mastcell of Cornhill was described by him prior to Ehrlich's observations upon the staining peculiarities of these cells, and may have been a myelocyte or a large mononuclear, and had best, therefore, be dismissed from the list of blood cells.

3. Carbol thionin: Saturated solution of thionin in 50-per-cent. alcohol, 20; 2-per-cent. carbolic acid, 100. (Should stand several weeks before being used.) Stain for from ten to fifteen seconds. Especially good for malarial parasite.

4. Eosin hæmatoxylon of Ehrlich: Eosin (cryst.), 0.5; hæmatoxylon, 2; absolute alcohol, 100; distilled water, 100; glycerin, 100; acetic acid, 100; glacial acetic acid, 10; alum (in excess), 50. (Should be made several weeks before using.) Alum aids in dissolving hæmatoxylon.

5. Müller's fluid, see p. 48, footnote. 6. Formalin solution for fixing blood, see p. 65. 7. Hayem's solution, see p. 40. 8. Pacini's solution, see p. 40. 9. Polychrome methylene blue (methylene blue, 1; potassium carbonate, 1; water, 100. Keep for several months before using.) 10. Toison solution, p. 43.

CHART ARRANGED BY THE WRITER FOR CLINICAL REPORT ON BLOOD; USED IN THE CORNELL DIVISION OF BELLEVUE HOSPITAL, NEW YORK CITY.

Name............ Record No............
Address..............................

Red Blood Corpuscles:

Size.......	Normally (1 $\mu = \frac{1}{25000}$ of an inch), 7 μ. Microcytes, 2–5 μ. Macrocytes, 8–10 μ.
Shape	Normally, biconcave discs. Poikilocytes, irregular outline. Crenated, spiculated.
Color	Normally, pale yellow. Colorless, shadow corpuscles Vacuolated, degeneration areas—deficiency in hæmoglobin.
Number per cubic millimetre.	Normal, 5,000,000. By Gowers' instrument................ By Thoma and Zeiss instrument........ By Daland's hæmotocrit................ By Oliver's hæmocytometer............
Nucleated red cells.	Normally, not present. Normoblasts. Megaloblasts or gigantoblasts.
Staining ..	Normally uniform. Polychromatophia = different intensity of stain in cells.

Malarial parasite.	Hyaline.	Ameboid....................	
		Non-ameboid................	
		Pigmented..................	
	Pigmented.	Intra-cellular.	One-fourth grown... One-half grown.... Full grown........ Pigment motile....
		Extra-cellular.	Non-flagellating ... Vacuolated........ Flagellating........ Non-vacuolated.... Pigment motile.....
	Segmenting................................		
	Crescents	Pigment motile......... Flagellating.............	
	Round bodies.	Pigment motile......... Flagellating	

Hæmoglobin:
Normal, 85 to 95 per cent.
By Gowers' hæmoglobinometer....................
By von Fleischl's hæmoglobinometer..............
By Oliver's tintometer...........................
By Roy's specific-gravity method.................
Color index (normal, 1)...........................

White Blood Corpuscles:

Number per cubic millimetre.	Normal 6,000 to 10,000. By Gowers' hæmocytometer........... By Thoma-Zeiss hæmocytometer....... By Daland's hæmatocrit............... By Friedländer's instrument...........

		Normal.
Number per each 100 leucocytes.	Small mononuclear lymphocytes	20–30%
	Large mononuclear lymphocytes	3
	Transitional lymphocytes.......	3
	Polynuclear leucocytes.........	60–70
	Eosinophiles....................	2.4
	Mastcells.......................	0.25
	Myelocytes...........	not present.
	Eosinophilic myelitis	"

Plates	Present (normal, 250,000 per cubic millimetre). Absent.
Plaques...	Present. Absent.
Fibrin.....	Present. Absent.

Blood Dust. { Present.
{ Absent.
Coagulation time (normal, two to three minutes).
Gross test.
Wright's coagulometer tubes.
Staining . . {
Fixation {
Heat { Flame.
Copper bar.
Sterilizer.
Alcohol and ether āā, equal parts.
Formalin (10 per cent. in 95-per-cent. alcohol).
Stain.
Remarks.

Ehrlich's Eyepiece (Fig. 598) supplies an important need. This instrument is so devised that accurate fields may be measured off on the dried specimen of blood and the relative numerical values of white and red corpuscles thereby ascertained. The instrument is constructed like an eyepiece, and may be fastened to the microscope in place of the eyepiece. A handle projects from one side of the instrument, and when this is moved the square aperture noted on looking through the eyepiece is seen to increase and decrease equally on all sides according to the direction in which the handle is turned. On the uppermost side of the square (see Fig. 598) three notches will be noted. When the handle is placed so that the square is at its greatest size the dimensions of this square will be just sixteen times that of the square formed when the first notch is covered. The second notch indicates a square four times as large as when the first notch is covered; the third notch indicates a square nine times as large; and the largest square, as stated, is sixteen times as large as the smallest.

Thus by counting all the red cells in the first or smallest square of a number of fields, and all the white cells in the fourth or largest square (which is sixteen times as large as the smallest) of a number of fields, and multiplying the number of red cells by sixteen, we get the ratio of red to white cells in a dried specimen.

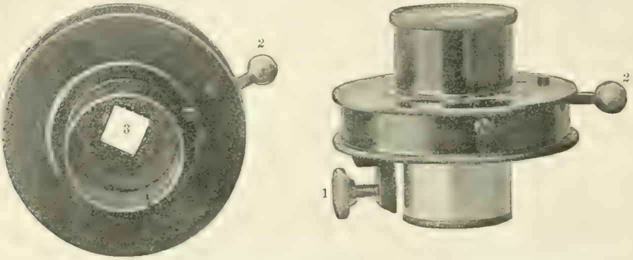

FIG. 598.—Ehrlich's Eyepiece for Determining the Relative Values of White and Red Cells in a Dried Specimen of Blood. 1, screw for fastening eyepiece to microscope; 2, handle by means of which the square aperture (3) may be altered in size; 3, aperture reducible to definite relative sizes by observing notches seen on upper margin of square.

ALKALINITY OF THE BLOOD.—Engel's (*Berliner klin. Woch.*, 1897) modification of the Löwy-Zuntz method for estimating the degree of alkalinity of the blood places the apparatus among those applicable for this purpose in bedside examinations. It consists of the following (Fig. 599):

1. A capillary pipette similar in construction to that used in the Thoma-Zeiss corpuscle-counting apparatus, but of somewhat larger size. The capillary portion is marked off into ten equal divisions. The fifth mark indicates 0.025 c.cm. and the tenth indicates 0.05 c.cm. Above the bulb portion is a mark that indicates 5 c.cm.
2. A receiver and a stirrer made of glass.
3. A burette measuring 5 c.cm., and marked 1, 2, 3, 4, 5 in equal divisions.
4. Litmus paper.

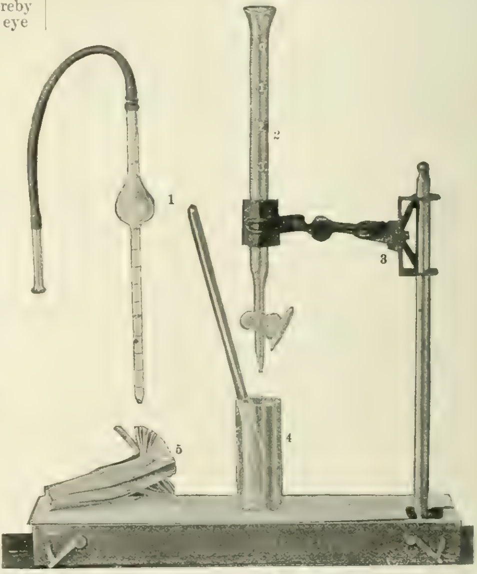

FIG. 599.—Engel's Apparatus for Determining at the Bedside the Degree of Alkalinity of the Blood. 1, Capillary pipette for taking and mixing definite quantities of blood; 2, burette for acid solution; 3, litmus paper; 4, receiver and stirrer for diluted blood while titrating.

To Make the Test.—Blood from the ear (taken in the usual way) is drawn up to the 0.05 mark and distilled water to the 5.0 mark. These are mixed by carefully shaking the pipette, and then the mixer is blown out into the glass receiver. In the burette is placed a $\frac{1}{75}$ normal tartaric acid solution.

As stated elsewhere in this article, a normal solution in chemistry is the sum of the atomic weights of the chemical employed (in grams) in 1,000 c.c. of distilled water. The formula for tartaric acid is $C_4H_6O_6$, and the sum of its atomic weights would be $\frac{C_4H_6O_6}{2}$—*i.e.*, $\frac{48 + 6 + 96}{2} = 75$. Therefore 75 gm. of tartaric acid in 1,000 c.c. of water would represent a normal tartaric acid solution. A $\frac{1}{75}$ normal solution, however, is all that is required, which would be: 1 gm. tartaric acid to 1 litre of distilled water.

This solution is then allowed to drop from the burette into the receiver containing the diluted blood, which is stirred from time to time with the glass stirrer. Blue litmus is immersed from time to time, and directly this turns red, showing an acid reaction, the titration is at an end, and the amount of acid solution required to accomplish this acid reaction (that is, the amount required to overcome the alkalies of the blood) is ascertained

TABLE OF DISEASES, THE DIAGNOSIS OF WHICH MAY BE MADE THROUGH THE BLOOD. THE CHARACTERISTICS OF EACH DISEASE ARE SHOWN IN THIS TABLE. THE DISTINCTIVE FEATURES ARE MARKED THUS (☞)

	Red blood cells.	Hæmoglobin.	Color index.	White blood cells.	Proportion of red to white blood cells.	Poikilocytes.	Microcytes and macrocytes.	Degeneration areas and polychromatophilia.	Normoblasts and gigantoblasts.	Small mononuclear lymphocytes.	Large and transitional lymphocytes.	Polynuclear leucocytes.	Eosinophile leucocytes.	Myelocytes.	Mastcells.	Plates.	Fibrin.	Coagulation time.	Blood dust.
1. Normal blood	5,000,000 to c.mm.	90 to 100%	1	6,000 to 10,000 to c.mm.	700 to 1	Absent	Absent	Absent	Absent	20 to 30 in every 100 leucocytes; 20 to 30%	6 to 8 in every 100 leucocytes; 6 to 8%	60 to 75 in every 100 leucocytes; 60 to 75%	2 to 3 in every 100 leucocytes; 2 to 3%	Absent	1 in every 400 leucocytes; ¼ of 1%	300,000 to c.mm.	Absent	2 to 3 minutes	Present
2. Primary anæmias. A, Chlorosis	4,000,000 to c.mm. normal	☞ Below 80% reduced	Low	Normal	Normal	Present	Present	Present	Absent	Normal	Normal	Normal	Normal	Absent	Normal	Normal	Absent	Normal	?
B, Pernicious........	1,000,000 to 3,000,000 to c.mm.; markedly reduced	Reduced, but above the reduction in red cells	High	Normal	Altered from normal 300 to 1	Present	Present	Present	☞ Present	☞ Increased 30 to 40%	Normal	Decreased 50 to 60%	Normal	Absent	Normal	?	?	?	?
3. Secondary anæmia	☞ 2,000,000 to 4,000,000 to c.mm.; reduced	Reduced in proportion to decrease in number of red cells	Fairly high	12,000 to 15,000 to c.mm.; moderate increase	Altered from normal 400 to 1	Present	Present	Present	Absent	Normal or decreased in proportion to polynuclear increase	Normal	Increased 75 to 80%	Normal	Absent	Normal	?	?	?	?
4. Addison's disease ... and 5. Hæmochromatosis...	☞ Normal, may be slight anæmia	Normal	According to grade of anæmia	Normal	Normal	Absent	Absent	Absent	Absent	Normal	Normal	Normal	Normal	Absent	Normal	Normal	Absent	Normal	Present
6. Anæmia, pseudo-leukæmia infantum.......	☞ Reduced	Reduced	do.	☞ Greatly increased 100,000 to c.mm.	Altered. 18 to 1	Present	Present	Present	☞ Present	☞ Increased	Normal	Decreased	Normal	☞ Present	Normal	?	?	?	?
7 Leucocytosis. A, Leukæmia. (1) Lymphatic......	Normal or slightly decreased	Normal or slightly diminished	do.	☞ Marked increase, 70,000 to c.mm.	Altered, 30 to 1	May be present	May be present	May be present	Not present unless anæmia exists	☞ Increased 70 to 80	Normal or slightly increased	Decreased	Normal	Absent	Normal	?	?	?	?
(2) Spleno-medullary or hemo-myelogenous myelocytic	Normal or slightly decreased	Normal or slightly decreased	do.	☞ Very greatly increased 150,000 to c.mm.	May be as low as 1 to 1	May be present	May be present	May be present	Not present unless anæmia exists	Decreased	Normal	Decreased	Normal	☞ Present	☞ Increased	?	?	?	?
B, Inflammatory. Polynuclear.....	Normal	Normal	do.	Increased 12,000 to 40,000 to c.mm.	Slightly altered	Absent	Absent	Absent	Absent	Decreased	Normal	Increased 75 to 80%	Normal	Absent	Normal	?	?	?	?
C, Trichinotic, etc. Eosinophilic....	Normal	Normal	do.	Increased	Normal	Absent	Absent	Absent	Absent	Normal	Normal	Decreased	Increased as high as 89%	Absent	Normal	?	?	Normal	?
8. Hodgkin's disease.. ..	Normal. May be reduced	Normal. May be reduced	do.	☞ Normal	Normal	Absent. May be present	Absent. May be present	Absent May be present	Absent	Normal	Normal	Normal	Normal	Absent	Normal	?	?	?	?

by noting the level at which the liquid stands in the burette.

There is no one alkali in the blood which we can hold responsible for its alkaline reaction. It is therefore necessary to measure this alkalinity by taking a known alkali, say NaHO, as the unit. By ascertaining the amount of a $\frac{1}{75}$ normal tartaric acid solution required to neutralize a known quantity of blood, and then ascertaining the amount of sodium hydrate neutralized by this amount of a $\frac{1}{75}$ tartaric acid solution, we learn in terms of NaHO the amount of tartaric acid required to neutralize a known quantity of blood. Things which are equal to the same are equal to one another.

Thus by experiment we find that 0.5 c.cm. of $\frac{1}{75}$ normal tartaric acid solution neutralizes 0.05 c.cm. of blood; *then* 1,000 c.cm. of $\frac{1}{75}$ normal tartaric acid solution neutralizes 100 c.cm. of blood.

Again, by experiment, we find that 75 gm. of tartaric acid neutralizes 40 gm. NaHO ($23 + 1 + 16 = 40$). 1 gm. of tartaric acid neutralizes ($\frac{1}{75}$ of 40) 533 mgm. of NaHO.

Since 1,000 c.cm. of $\frac{1}{75}$ tartaric acid solution neutralizes 100 c.cm. of blood, 100 c.cm. of blood has an alkalinity of 533 mgm. of NaHO.

0.5 c.cm. of $\frac{1}{75}$ normal tartaric acid solution neutralizes 0.05 c.cm. of blood. 1,000 c.cm. of $\frac{1}{75}$ normal tartaric acid solution neutralizes 100 c.cm. of blood. 75 gm. of tartaric acid solution neutralizes 40 gm. of NaHO.

$C_4H_6O_6 = \frac{48 + 6 + 96}{2} = 75$ neutralizes NaHO $= 23 + 1 + 16 = 40$.

Then 1 gm. of tartaric acid solution neutralizes ($\frac{1}{75}$ of 40) 0.533 NaHO.

This is the quantity of tartaric acid in the $\frac{1}{75}$ normal solution (1 gm. in 1,000 c.c. of water). This, therefore, is the value in alkalinity—so to speak, in terms of NaHO—of the tartaric acid solution employed.

Now on titration it is found that from 9 to 10 drops of such a solution are required to neutralize 0.05 c.cm. of blood.

10 drops equal 0.5 c.cm., which equal 0.5 gm.

0.5 gm. equals 0.266 NaHO.

Therefore 10 drops equal an alkalinity of 0.266 NaHO.

1 drop = 0.0266 NaHO.

It is perhaps better to bear in mind that 9 or 10 drops represent the normal, and to report examinations accordingly. For example, "6 drops required to neutralize," "12 drops required to neutralize," etc. It would also simplify the proceeding to use a solution of litmus in the blood solution instead of the papers.

The Eyepiece Micrometer (Fig. 600) is of so simple construction and mechanism that its employment is to be recommended for more accurate clinical reports on the size of the blood corpuscles.

The following explanation is taken from the Leitz advertisement of the instrument:

Micrometric Measurements.—The scale of the eyepiece micrometer is divided into $\frac{1}{10}$ mm. Each of these divisions represents, according to the objective used, a certain absolute linear measure of the object, as shown in the following table:

Number of objective.	Absolute length of object represented by one division of the eyepiece-micrometer scale. Millimetres.	Number of objective.	Absolute length of object represented by one division of the eyepiece-micrometer scale. Millimetres.
1	0.054	7	0.0026
2	.028	8	.0020
3	.015	9	.0017
4	.012	Immersion $\frac{1}{10}$	.0022
5	.0048	" $\frac{1}{12}$	.0018
6	.0034	" $\frac{1}{18}$	.0014

When making micrometer measurements it is absolutely necessary accurately to maintain the tube length at 170 mm. If this is neglected the measurements become unreliable or even worthless.

The above micrometer values are measured with eyepiece II.; in the other eyepieces they differ in an inappreciable degree.

Example: Let a scale of *Hipparchia Janira*, as seen with objective 6, cover 54 divisions of the scale longitudinally and 20 divisions transversely. Its actual length will then be 54 × 0.0034 = 0.184 mm., and its breadth 20 × 0.0034 = 0.068 mm.

Suppose a valve of *Pleurosigma angulatum*, measured with objectives 4, 6, and 7, to cover 21, 74, and 98 divisions respectively; then the measurements of its length represent the following absolute dimensions:

Objective 4: 21 × 0.012 = 0.252 mm.
" 6. 74 × 0.3004 = 0.252 "
" 7: 98 × 0.0026 = 0.255 "

Tables of Magnifications.—The image seen in the microscope produces upon the eye the same effect as an object seen at the normal distance of distinct vision, *i.e.*, 10 inches.

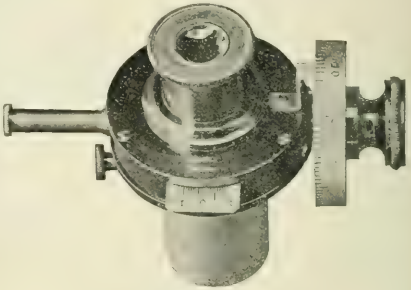
FIG. 600.—The Eyepiece Micrometer.

If, therefore, a rule be placed at the foot of the microscope at a distance of 10 inches from the eye, it can be compared with the microscopical image of a scale divided into $\frac{1}{100}$ mm. The quotient is the magnification of the objective and the eyepiece combined.

If, *e.g.*, 92 mm. of the rule are found to cover $\frac{7}{10}$ of the image of the micrometer scale, it follows that the magnification is $\frac{92}{0.7} = 130$. The tables of magnification have been compiled in this manner and are sufficiently accurate for practical purposes.

Thus, supposing the same specimen of *Pleurosigma angulatum* to be measured—

(1) with objective 7 and eyepiece 0,
(2) with objective 4 and eyepiece II.,

and supposing the length of its image to be 67 mm. in the first and 22 mm. in the second case, then, since the actual size of the object is found by dividing the length of the image, as seen at a distance of 10 inches from the eye, by the magnification of the objective and eyepiece combined, the length of our specimen of *Pleurosigma angulatum* is:

(1) $\frac{67}{270} = 0.248$ mm.
(2) $\frac{22}{90} = 0.244$ mm.

In all these measurements a tube length of 170 mm. must be strictly adhered to.

(NOTE.—As this article goes to press I learn that Jolles's ferrometer has undergone such simplification as to place it among those instruments useful for clinical work.

The eyepiece spectroscope is also a valuable addition to our clinical apparatus.

Both of these instruments are as yet untested, but their simple construction and application commend them to the clinician.)

BIBLIOGRAPHY.

As space does not permit of a long list being introduced, the reader is referred to the very full bibliographical note in von Jaksch's "Clinical Diagnosis" and to the writings of the observers who are quoted throughout the article. *Charles N. B. Camac.*

BLOOD-LETTING.—This title includes all methods of abstracting blood for therapeutic purposes, whether they are for a general or for a local effect. The terms *venesection* and *phlebotomy* are restricted to bleeding from the larger veins, for the purpose of influencing the system generally; whilst *leeching*, *wet-cupping*, and *scarification* are means of abstracting blood from the capillaries, the effect of which is almost entirely local.

General blood-letting, or venesection, is of very ancient origin. References to it have been found in history prior to the time of Hippocrates, and in the writings of this early authority it occupies an acknowledged position as a valuable therapeutic agent. During the many years that it has been employed it has been viewed with a varying degree of favor, and at times its advocates have employed it in all forms of disease and in a most extravagant manner. The seventeenth century and the early part of the present century mark the periods of its greatest use, during which excessive and repeated bleedings were constantly employed. The amounts of blood removed seem astounding at the present day. For a pleurisy 5,520 gm. were abstracted during a period of several days; in a case of pericarditis it was found necessary to abstract, on different occasions, 721, 720, 960, 1,200, and then 1,440 gm. before the patient was relieved; and, in a case of inflammatory rheumatism, twenty pounds of blood were taken during the progress of the attack. In the early part of the century, medical opinion went to the other extreme; the practice fell into disrepute and was almost entirely abandoned. During the last twenty-five years its use has been revived. Many of the older practitioners who had never forsaken its use have been more outspoken in advocating its therapeutic powers. At medical gatherings, many papers have been read and numerous discussions have followed, in which venesection has been very generally supported. Its employment has now assumed a more rational character. The advance in our knowledge of physiology and a closer clinical observation have made clearer what its effects are upon the system, and we now employ it with a definite object in view and restrict its use to a much more narrow sphere.

Venesection exercises what may be termed a mechanical effect upon the circulation, as well as a general effect upon the system. When a certain proportion of the blood is removed the tension of the blood-vessels is at once lessened, the degree depending upon the amount withdrawn. The effect is but temporary, as that which is lost is rapidly renewed; but, if any disturbance of the circulation exists, it is sufficient to allow the equilibrium to be regained, the heart beating more easily and the blood flowing more freely through the vessels.

The general effect upon the system is of the utmost importance. Accompanying the lowering of blood pressure and loss of blood cells, there is a diminished activity of the various functions. The heart's action is quieter, respiration goes on more slowly, tissue changes are less active, and there is a lowering of body heat. This depression is but temporary. In a few hours there begins a renewal of the blood, tissue changes are accelerated, the nervous system is improved by a stimulation of the nerve centres, and general bodily improvement is the result. At the International Medical Congress for 1900, in the discussion upon this subject, M. A. Robin stated, as the result of many years' observation, he was satisfied that after moderate bleeding of 150 to 250 gm., polyuria is regularly observed, and the excretion of solids is increased. A greater amount of air is taken into the lungs, as much as sixty-one per cent., and the proportion of oxygen consumed by the tissues is correspondingly increased. When the bleedings are renewed the reaction is slower, and when they are frequently repeated, a state of anæmia ensues, with a tendency to degenerative changes.

INDICATIONS.—The indications for bleeding may be summed up under three heads: (*a*) when there is excessive vascular tension; (*b*) when it is desired to obtain the benefit of its physiological action upon the various tissues and organs; (*c*) when it is believed that good may result from removing a definite amount of blood, and with it a certain proportion of toxic material, from the system.

There is no difference of opinion as to the value of venesection in all conditions in which there is venous engorgement. It may be thought desirable to try the nitrites and allied drugs for the purpose of "bleeding into the arteries," or to employ hydragogue cathartics or diuretics to unload the congested vessels; but if these measures fail, all are in favor of bleeding. The cause of the obstructed circulation may lie in the heart or in the pulmonary tissue. The effect of either of these causes is an overfilled and possibly a dilated right heart, distended veins, and more or less congestion of the various organs. In this condition the removal of blood from the venous system affords prompt relief. The laboring heart beats more freely, the arteries become filled, and the congested veins and organs return to the normal. The dyspnœa disappears, the dusky hue of the skin fades, and the general condition of the patient is at once improved. Mitral disease, when compensation is failing, and a feeble heart that is suddenly overtaxed, are the two conditions that most frequently give rise to these distressing symptoms. In such cases, when the dilatation is extreme and the force of the heart very low, venesection must be prompt to be of service. Among these cases may be included many instances of cardiac failure that occur during the administration of a general anæsthetic, when the dilated heart becomes suddenly overfilled and unable to empty its cavities. A sudden blow over the heart may suffice to cause a powerful contraction, or the withdrawal of blood will relieve the pressure and allow regular contractions to be re-established. Of the pulmonary causes of venous congestion, emphysema is the most common, and in this condition marked benefit will follow the withdrawal of blood. Cases of bronchitis and those in which there is a tendency to pulmonary œdema afford favorable conditions for this treatment.

Venesection is also of service when the arteries show a condition of increased tension, when the pulse is full and bounding, and when a condition of general plethora prevails. In these cases the relief afforded by the withdrawal of blood is also very marked, the reduced blood pressure relieving the congested organs and often preventing cerebral hemorrhage. In the convulsions of uræmia, and especially in puerperal eclampsia, when there is the same arterial tension, the value of venesection is unquestionable. The relief is immediate, and the severity of subsequent attacks is likely to be lessened. In puerperal states there should be no hesitation in resorting to it, if the arterial tension is abnormally high; and the fact that a free loss of blood has occurred during labor does not warrant the belief that venesection will be any less effective in relieving the tension. In these cases much of the benefit is due to the reduction of blood pressure, and much also may be explained by the favorable influence exerted on the tissue changes and by the increased oxidization. In addition, it is also suggested that the increased nutritive changes neutralize the poisons circulating in the blood and convert them into harmless products.

It is difficult to determine to what extent the benefit should be ascribed to the actual removal of toxic material from the body (with the blood that is drawn off), yet we find that there are many eminent authorities who lay great stress upon this explanation. To increase the usefulness of the procedure in these toxic cases, it is recommended that the bleedings should be very free and that the blood lost should be replaced by normal saline solution, either administered subcutaneously or injected directly into the veins.

The effect of venesection in lowering temperature and allaying the symptoms of inflammation would suggest the wisdom of employing it in the treatment of fevers and inflammatory diseases—a practice which was so much in vogue at the time when venesection was used empirically. This proposition, however, does not meet with favor. It is maintained that the relief afforded is but temporary, and that the tendency to fatty changes, present in pyrexia, is heightened by the repeated withdrawals of blood. The symptoms undoubtedly show marked improvement immediately after the operation, but the greater debility which results and the prolonged convalescence prevent its general acceptance. The only acute disease in which venesection receives much attention is pneumonia. In addition to the benefits derived from the lessening of the plethora and the easing of the overworked heart, the lessening of the inflammatory process and the probable limiting of the extent of the consolidation must also be considered as results of some value. At all events numerous cases have been reported in which venesection has proved serviceable, and the subject is therefore worthy of every consideration. It is evident, however, that if any benefit is to be derived from this method of treatment it must be begun early before the pathological processes have made much advance. When it is resorted to at the outset, in a plethoric patient with sthenic symptoms, a full pulse, difficult respiration, pain, and fever, the operation acts most favorably, and there is every reason to believe that it renders the attack less severe. Frequently the venesection is resorted to too late in the disease as a last resort, and although the distressing symptoms may be allayed for the moment, the ultimate result is rarely favorable.

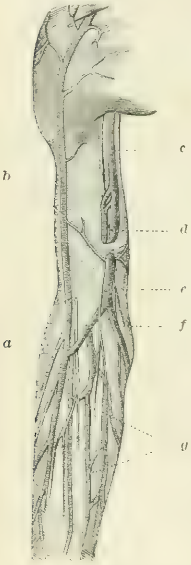

FIG. 601.—The Superficial Veins of the Forearm; Skin Removed. *a*, Median cephalic; *b*, cephalic; *c*, brachial; *e*, basilic; *f*, median basilic; *g*, anterior ulna; *d*, median nerve.

METHOD OF PROCEDURE.—Formerly, blood was withdrawn from the veins of the arm, the external jugular, the veins beneath the tongue, the scrotal veins, and the veins of the leg; but at the present time a vein on the anterior surface of the forearm is the one chosen, unless some particular reason exists why another should be selected. The veins in this region that become most prominent, when the circulation in them is arrested, are the median cephalic and the median basilic. The former is the proper one to select, as the median basilic is in close relation to the artery. The median cephalic is external to the tendon of the biceps and away from any region of danger. It will be found, however, that the size and prominence of the veins in front of the elbow vary greatly, and generally the most marked one is selected regardless of its name or position.

In performing the operation strict antiseptic precautions should be observed in the preparation of the site and in the selection of the knife and dressings. The arm is allowed to hang suspended and a firm bandage is applied above the elbow, sufficient force being employed to compress the superficial veins, and yet not enough to intercept the arterial flow. The vein is opened either longitudinally or in a direction slightly oblique to the axis of the vessel, the point of the blade being inserted directly into the vessel and withdrawn with a downward cutting motion. Before one makes the incision he should place the thumb of the left hand below the point of opening, in order to secure the vessel firmly. Care must also be observed that the skin is tense and in its proper relation to the vessel, otherwise the incision through the skin may not coincide with the opening into the vein, and instead of a free flow of blood there will be only an exudation of blood into the cellular tissue. As soon as the blood flows freely, the pulse of the other arm and the patient's face should be kept under observation to determine the effect on the circulation and to detect any symptoms of syncope. Twenty, thirty, or even forty ounces should be removed, according to the condition and temperament of the patient. The quantity taken should always be sufficient to make a decided impression upon the circulation. Frequently the amount withdrawn does not exceed a few ounces. This is too small a quantity to afford any benefit to the patient, and as a further result venesection is discredited. When sufficient blood has been removed the flow is readily checked by applying a compress over the incision, removing the constricting band, and bandaging the arm, which bandage may be removed in twenty-four hours.

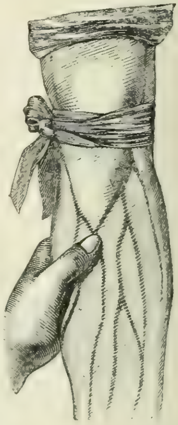

FIG. 602.—Forearm with Ligature Applied. Finger at junction of median basilic and median cephalic veins.

It is often desirable to abstract blood from some prominent part for the purpose of relieving a local hyperæmia or congestion, as in many bruises and ecchymoses, in disease about the eye, nose, ear, gums, etc., and in some forms of cellulitis. Such local blood-letting is also occasionally employed to lessen the congestion of deep organs by withdrawing blood from the surface of the body near to the affected part. In all cases the blood flows from the capillaries or superficial vessels, and the quantity is very slight in comparison with that which is abstracted in general blood-letting. To accomplish this end, leeches, scarification, and wet-cupping are the means employed.

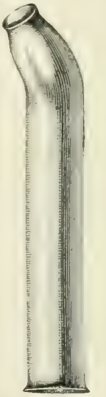

FIG. 603.—Glass Leech Tube.

LEECHING.—This means of locally abstracting blood is still frequently employed, but not to such an extent as formerly. When any large amount of blood is required, a number of leeches must be used. A single leech will absorb from two to three drachms of blood, and this may be increased as much more by warm fomentations applied after the leech has dropped off. The leeches may be placed in a wine glass which should then be inverted over the desired spot. If the area is very limited, or if the blood is to be withdrawn from the nasal cavity, gums, or any cavity, a leech glass should always be utilized. The leech will bite more freely if removed from the water an hour or more before needed, and for the same reason the part should be thoroughly cleansed. When a leech shows no inclination to bite, rubbing the skin with sweetened water will sometimes induce it to fasten upon the spot. The peculiar bite of the leech always leaves a permanent scar, and care must be observed in selecting a site which is not conspicuous.

Scarification and Cupping.—By these means blood is abstracted through small superficial incisions into the skin, the flow being augmented by the cupping glass when that instrument is employed. The incisions may be made with an ordinary knife or lancet, or by means of a scarificator. In the latter instrument the blades may be adjusted to any desired length so that the cutis vera of the part may be incised without penetrating to the deeper tissues. The cupping glass may be one of those specially constructed for this purpose, or an ordinary wine glass may be made to serve the same end. The cavity of the glass is heated over a spirit lamp, or by burning a small quantity of spirit in it, and then the glass is quickly inverted over the desired part and placed in such a way that the air will not enter. As the heated air cools its density is increased and suction force is exercised upon the incised surface. The glass should be removed as soon as it ceases to act and a fresh one applied. A cupping glass with a rubber bulb attached, on the principle of the ordinary breast pump, is also utilized.

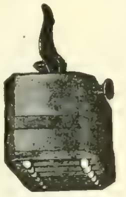
Fig. 604.—The Scarificator.

Dry Cupping.—Very frequently cupping glasses are applied without an incision being made for the removal of blood. This is known as "dry cupping." The application of the glasses produces a rapid flow of blood to the part, and when repeated rapidly over a small area, the withdrawal of blood from organs lying below the surface is sufficient to relieve them if inflamed and congested. A single glass may be applied and quickly reapplied, but it is more satisfactory to employ a number of glasses and apply them at the same time. They are applied after the same manner as described for wet cupping. Dry cupping has the advantage of not making any incision and not causing any scar. The therapeutic action is somewhat different from that of wet cupping, as the counter-irritation is much greater and more prolonged. Junod's boot is an instrument prepared on the same principle as that of the cupping-glass, its purpose being to withdraw blood from the body into one of the limbs, in order that relief may be afforded to congested organs without the permanent loss of any blood. It consists of a metallic vessel into which a limb may be placed and which closes so tightly that air cannot enter or escape, except by means of an exhausting syringe. As the air is withdrawn from the cavity, the blood flows into the vessels of the limb which becomes greatly swollen and congested. This appliance has never met with much favor, as the constitutional effect is not very satisfactory and the local action is often severe.
Beaumont Small.

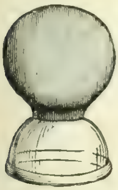
Fig. 605.—Cupping Glass, with Elastic Rubber Cap or Bulb.

BLOODROOT.—Sanguinaria. *Red Puccoon.* "The rhizome of *Sanguinaria Canadensis* L. (fam. *Papaveraceæ*), collected in the autumn" (U. S. P.). It is doubtful if this definition can be complied with, as the aerial portions die in early summer, and before fall all traces which would indicate the presence of the rhizome have disappeared. The plant is a low perennial, with a thick, fleshy, horizontal root-stock, from which one or two leaves and a single handsome white flower appear early in the spring, enclosed at the base by several sheathing scales. The leaves are kidney-shaped, variously lobed, and grow much larger and broader as the season goes on. The flower is about 3 cm. across (one and one-fourth inches), regular, perfect, spreading; sepals two, falling early; petals from six to twelve, rather narrow; stamens numerous, ovary and capsule one-celled, with two placentæ; ovules (and seeds) numerous, with prominent caruncles. An opaque, orange-colored juice is found in all parts of the plant, especially in the rhizome, where it is very abundant and dark. Bloodroot is a native of North America, and is occasionally cultivated as an ornamental plant both here and in Europe. The dried rhizome is about 5 cm. (two inches) long, and 1 cm. in diameter, slightly flattened, indistinctly annulated, and evidently shrunken and wrinkled. It is reddish brown externally, variously bent and twisted, and now and then branched. It breaks with a short fracture, and displays a pink surface, finely dotted with dull red points; this surface becomes dark by exposure, and finally is uniformly brownish red. Odor slight, disagreeable. Taste bitter, acrid, nauseous, and persistent. Powder sternutatory.

The principal constituent is the alkaloid *sanguinarine* ($C_{20}H_{15}NO_4$), discovered and named by Dana in 1829. When pure it is in white crystalline needles or tufts, insoluble in water, but easily dissolved by alcohol, ether, oils, etc.; it forms with the principal acids beautiful salts of brilliant orange or red color. The powder excites violent sneezing. Its taste, when dissolved, is that of the rhizome intensified. Chelerythrine ($C_{21}H_{17}NO_4$) exists in smaller amounts and yields yellow salts. Small amounts of at least two other alkaloids exist, with irritant resin, starch, citric and malic acids.

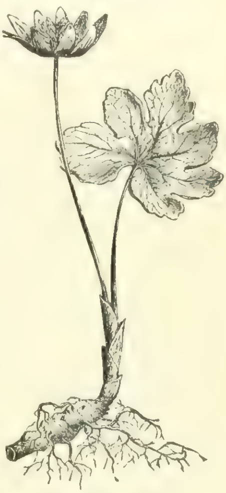
Fig. 606. Bloodroot.

Action.—The several alkaloids of bloodroot have very dissimilar actions when used separately, but that of sanguinarine is overpowering and determines that of the drug. It is a most powerful irritant, locally and systemically. It was formerly used as a caustic for morbid growths, and has had many uses as a counter-irritant. It is powerfully irritant to the mucous membranes, and sialagogue. It is a powerful and even fatal emetic and cathartic. Systemically, it irritates both the spinal and cerebral centres, producing tetanic convulsions and intoxication or violent delirium. It depresses muscular fibre, and this at length greatly depresses both the circulation and the respiration.

These properties can be utilized, by small doses, in improving both appetite and digestion, and in producing expectorant effects, the latter either by internal administration, or by inhalation of very weak preparations, or by application to the throat. It was formerly a much-used emetic in doses of gr. xv. to lx., but this use is now considered barbarous. It is very little used at the present time, and then chiefly as an expectorant, in doses of 0.2 to 0.5 gm. (gr. iij. to viij). Its excretion is accompanied by stimulation of intestinal and renal secretion and of peristalsis. It is also a stimulating emmenagogue. A fluid extract and a fifteen per cent. tincture, each containing a little acetic acid, are official. *H. H. Rusby.*

BLOOD STAINS.—In criminal trials the medical witness is often called to determine whether stains found on weapons—as knives, clubs, or daggers—or upon the clothing of a suspected person, or upon the floor, walls, or ground where a homicide is supposed to have been committed, were caused by blood or by some other coloring matter. So also it is often equally important to determine whether stains acknowledged to be blood are the blood of a human being or that of one of the lower animals. The object of this article is to show how, and to what extent, these important questions may be answered. Such investigations have often served to convict the guilty, and in other cases triumphantly to acquit the innocent.

The examination of blood stains calls for the consideration of: (1) physical characteristics; (2) chemical reactions; (3) crystalline properties; (4) optical properties; and (5) microscopical appearances of blood corpuscles and other constituents of blood.

1. PHYSICAL APPEARANCE OF BLOOD STAINS.—The color of blood stains varies with the amount of serum and the absorbent properties of the object upon which the stain dries. Generally the more permeable the tissue or object stained, the brighter is the color after blood has dried upon it.

Upon polished steel or other metal, blood dries in dark brown, shiny scales, however thin the blood may be. Upon silk or glass it assumes about the same color as upon polished metal. Upon varnished or very hard wood, blood stains have also a dark shining surface. Put upon soft porous wood, or any soft tissue, as cotton cloth, the blood displays a dull brown color or a rose tint, yet even on cloth a thick clot, when dry, presents a brown but glistening surface.

It sometimes happens that upon tissues or objects of a brown, maroon, or dark blue color, blood stains are quite invisible by full daylight, but they become conspicuous by artificial light, especially if examined by light obliquely reflected. This is especially the case with dark-colored furniture, wallpaper, or any dark paint, on which blood stains easily seen by the light of a candle are quite invisible by daylight.

Stains upon steel or other metallic instruments, if quickly dried by exposure to the air, are cracked and of a fine red color; but stains on similar instruments, kept in a damp situation, are of a dirty brown, tending toward a yellow rusty color, surrounded with an ochrey areola, yielding no color or albumen in water; even a solution of potash extracts only a small quantity of albumen.

Upon glass, marble, plaster, flint, sandstone, and earth, blood stains preserve their ordinary characteristics; but upon wood containing tannin they form with the tannin an insoluble compound, and water in which such stains are macerated fails to yield characteristics of blood. In such cases the surface can sometimes be scraped off and tested free from the tannin.

On felt and some kinds of cloth, blood forms shiny spots appearing like mucilage. In examining garments, searching for blood stains, a small magnifying glass is of great service in distinguishing small specks or drops of blood.

2. CHEMICAL REACTIONS.—(*a*) *Guaiacum Test for Blood.*—If any red substance is suspected to be blood, place a drop on white paper; or if dry, moisten with water and then place it on the paper. Let fall upon the stain thus formed a drop of tincture of guaiacum. If the stain turns blue with no other treatment it is not blood; or if it contains blood it also contains starch, a salt of iron, or some other foreign substance. If it does not turn blue by the action of the guaiacum, drop upon it a watery solution of hydrogen dioxide, when, if it is blood, it will quickly assume a beautiful sapphire blue color. A particle of blood scarcely visible to the naked eye may be detected by this test. If the blue color does not quickly appear by this test it is not blood. If the stain gives the blue color by this test it may be blood; and other tests may be applied to determine with certainty that it is. The white paper should be tested with guaiacum and dioxide before the stain is applied.

(*b*) *Action of Solvents and Other Reagents.*—Stains upon cloth may be cut out and suspended in a test tube containing distilled water. The bottom of the cloth should dip into the water, but the stain should not touch the sides of the tube. Under these circumstances the coloring matter of blood will usually detach itself from the tissue and fall in reddish striæ to the bottom of the tube.

When a solution of blood is heated the color disappears, but vegetable colors in general are unchanged by heat. A solution of blood is made a little darker by the addition of a small quantity of ammonia, but the color is not destroyed. The red, pink, or scarlet infusion of fruit or flowers or roots and the juices of fruits are changed to green or violet by ammonia, and cochineal is changed to crimson. Hypochlorous acid quickly destroys all organic coloring matter except blood, which withstands the acid much longer. Two minutes are sufficient to destroy most colors except that of blood. Stains of colcothar and grease and those of rust resist for a long time the action of hypochlorous acid, but disappear instantly on contact with chloride of tin, which does not act upon the coloring matter of blood. Carbon mixed with the colored fluid cannot be readily discolored by any reagent.

If the stains are upon weapons, from which it is impossible to detach a superficial layer, they may be moistened with drops of water. If they are upon wood, plastered wall, or stone, we may scrape the surface and test the material removed. If upon the point of a dagger or other narrow blade, this material may be placed in a tall, narrow vessel. In general, if the material of the stain can be scraped off, the fine powder thus obtained may be treated with a minute portion of fluid in a test tube, watch glass, or on a concave slide or cover glass, such as is used with the microscope. The method of dealing with minute specks, when these are all that can be obtained from a stain, will be described further on. If the powder obtained is abundant and contains foreign matter, it may be placed in a small gauze bag and suspended in a test tube as described above. If the stains are spread in streaks on the surface of the instrument, a plate of glass may be adjusted on a perfect level, and a few drops of distilled water placed on the glass; then the instrument should be so arranged that the stain touches the water while the instrument does not touch the glass. After one or two hours the water will be colored by the stain; but whatever process we employ, it is important to avoid contact of the water with the steel or iron so as to form rust. In all cases only a small quantity of water should be used, and if the liquid contains much foreign matter it should be filtered before using reagents.

3. CRYSTALLINE PROPERTIES.—Crystals characteristic of blood were discovered by Teichmann, and great importance is attached to this test. To obtain hæmin crystals, digest the stained tissues, or the powder obtained from the stain, in a one-fourth-per-cent. solution of common salt for twenty-four hours, next allow the fluid to dry on a glass slide at a temperature of 80° or 100° F., and then apply a drop of glacial acetic acid, heating it over the flame of a lamp. As the fluid evaporates a great number of crystals appear, in the form of rhomboidal plates with angles of 55° and 125°, of yellow, red, or brown color, depending on the thickness of the crystalline plates. In the dog and in man they are long parallelograms. In the squirrel they are hexagonal plates; and in the guinea-pig they are in the form of tetrahedral crystals. The length of the crystals from human blood is from one and one-half to three times the breadth. They are generally very small, and if obtained from minute stains their obtuse angles are somewhat rounded, as are the crystals of uric acid found in the brick-dust sediments of urine.

The microchemical examination of stains to produce *hæmic crystals*, or crystals of hæmatin, or Teichmann crystals, when only minute stains are to be examined, is so important that we deem it desirable to give the following directions, which we have translated from "Précis de médecine légale," by Ch. Vibbert:

"The Teichmann crystals are so characteristic that when once seen they are ever afterward easily recognized. The operations for obtaining them are exceedingly simple, but require great care and patience. To avoid failure, persons but little accustomed to these minute investigations should follow carefully the methods here described, especially if, as often happens, only minute portions of the suspected material are available for these researches.

"(*a*) *Solution of the Stain.*—If the stain is small and no speck or clot that may be removed can be seen, cut out the stain, following the edges of it, with a pair of scissors; place the stained piece of cloth on a glass slide, and put on it a few drops of water—just enough to moisten it, for it is better to get a solution somewhat concentrated. After macerating till the liquid is considerably colored, press out the liquid with a scalpel or needle, and remove the cloth, leaving the colored fluid on the slide. Avoid spreading the liquid, but dry it slowly, so that it shall make a small, deeply colored spot on the glass: not entirely opaque but somewhat transparent, so that the preparation can be examined with the microscope.

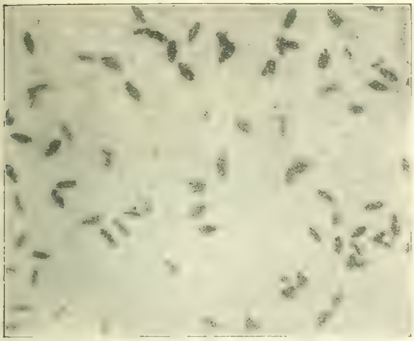

FIG. 607.—Hæmin Crystals.

"If the stains are very small, several may be taken and macerated together to obtain sufficient coloring matter for the subsequent manipulations. If the stain is on wood, a thin layer of the wood may be removed by a sharp knife or lancet, and treated as directed for a fragment of cloth; only the maceration should be continued much longer.

"If it is not possible to lift the stain from the object, a ring of wax may be formed around it, making an inclosure that will hold a little water, which is then applied to absorb the stain. When the water has absorbed the coloring matter, it may be transferred to the slide by means of a pipette.

"(*b*) *Evaporation of the Liquid.*—We may allow the liquid to evaporate spontaneously, but the evaporation can be hastened by the employment of heat, it being necessary, however, to heat the liquid very moderately, not exceeding a temperature of 60° C. (140° F.); for if the heat is sufficient to coagulate albumen, it prevents the extraction of the coloring matter, and of course no crystals will be obtained. We generally warm the slide over the flame of an alcohol lamp, being careful that the temperature does not exceed that which is not uncomfortable when the slide is laid upon the back of the hand. It is important to heat the liquid around the borders and not in the centre, so as to prevent its spreading over the slide, which would much interfere with subsequent operations.

"(*c*) *Action of Reagents.*—To the evaporated residue a little common salt should be added. Too much is injurious. It is better to make a solution of 1 part of chloride of sodium to 500 or 1,000 parts of distilled water, and add one or two drops of this solution. *It is more convenient to use this solution in the first place for dissolving the stain*, instead of using simple distilled water. It saves time and nothing is changed. Sometimes crystals can be obtained by treatment with acetic acid without the addition of salt, there being sufficient chloride of sodium in the blood; but it is better to add the salt than risk a failure in an important case.

"At whatever stage the process the chloride of sodium has been added, the preparation must be thoroughly dried afterward before the acetic acid is applied. This acetic acid monohydrate is called glacial or crystallizable. It solidifies at the freezing point, or zero Centigrade, and does not again liquefy until the temperature is raised to 17° C. The addition of a small quantity of water transforms it into acid hydrate, which interferes with this reaction.

"Place a drop of acetic acid monohydrate on the preparation and evaporate with heat, which may be increased and continued, though the evaporation will be more successful if the heat does not quite reach the boiling point. When there is only a small quantity of the suspected material, it is especially important to use all these precautions. The acid should be taken up with a tube drawn out to a fine point, so that only a very small drop may be added at a time; place the droplet in the centre of the red deposit on the slide, and allow it to spread a little, but not to spread beyond the limit of the stain; for this purpose the heat of the lamp should be applied around the borders at various points, tipping the slide as may be necessary to retain the fluid on the red deposit only; a red line is thus formed about the borders when the coloring matter becomes thickened, and the acid remains on the stain till evaporation is completed. It is on this border that the crystals are commonly formed, and they are to be looked for by aid of the microscope.

"It is not common to find crystals after adding only a single drop of acid, but it is generally necessary to add drop after drop, evaporating each with the greatest care, examining the specimen from time to time where the red lines are formed one after the other as it is repeatedly treated with acid and dried. When this experiment is performed under favorable conditions, a multitude of distinct crystals are found. Often, however, we find only irregular masses of brown or dark coloring matter, and the remainder of the preparation filled with coagulated albumen and foreign bodies which have become mixed with the stain. If we have added solid particles of chloride of sodium to the coloring matter, we are apt to find crystals of this salt formed in cubes, in stars, or in small, colorless globules, and even lance-shaped crystals of acetate of sodium may be formed. All of these crystals, arranged together in beautiful forms, may often be found.

"In such cases, we select a point where the coloring matter is collected in considerable quantity, and there apply another small drop of acid and let it evaporate as before. By repeating this operation we sometimes obtain a large collection of very small crystals mingled with other matter; but when we find crystals in the form of a cross or a star, it is very certain that they are chlorohydrate of hæmatin, and we may perfect the preparation by the addition of small drops of acetic acid.

"If doubt still remains in regard to the nature of the crystals, the specimen should be examined by the aid of polarized light. The albuminous or saline substances allow the field to remain dark, but the crystals of hæmatin appear bright on a dark field.

"By carefully following the precautions stated above, one can almost always obtain crystals of hæmatin, even with a very minute quantity of blood. The reaction is successful with very old stains. Many experts have obtained crystals of hæmatin from stains of blood ten, fifteen, and even forty years old. It sometimes happens, however, that it is impossible to obtain crystals when the stains are only a few months old. This is especially the case when the blood has been allowed to putrefy before drying. Contact with perspiration, grease, or tannin also seems to interfere with the formation of crystals.

"Two sources of error are to be noticed in connection with this test for blood. Crystals of murexide (purpurate of ammonia) have a form very similar to that of crystals of hæmatin, but they are of a bright red, and they acquire a violet color by contact with a solution of potash; again, it is very difficult to imagine how it can be possible to obtain crystals of murexide by treating a stain with common salt and acetic acid. A mistake may easily occur with crystals formed with indigo. Cloth colored with this material will sometimes furnish a deposit of crystals which will not dissolve in acetic acid and which have a form very similar to that of crystals of hæmatin. Their color is blue, it is true, but when the color is very deep it can scarcely be distinguished from brown. Descoust, by simply washing with water a piece of flannel of blue violet color, obtained crystals having almost exactly the form and reddish-yellow color of crystals of hæmatin. This is a more serious source of error than is generally admitted in books on legal medicine.

"When a stain to be examined is found on clothing colored with indigo, it is important before examining the stain itself to examine pieces of the garment which are not stained, to see whether they will deposit crystals of indigo. The comparison between these crystals and those obtained from the stain may remove all uncertainty. if, for example, the crystals obtained from the stain are very numerous, while those obtained from the unstained cloth are very few and of a blue color. If the similarity of the two species of crystals is very close we may try the guaiacum test. The crystals of hæmatin will color the guaiacum blue, while those of the indigo will have no effect upon it.

"When the crystals of hæmatin have been obtained they may be indefinitely preserved by adding a little glycerin and covering the preparation with thin glass. The expert should carefully preserve the preparation, to serve as a proof of the correctness of his conclusion."

4. SPECTRUM ANALYSIS OF BLOOD STAINS.—One of the most important methods of distinguishing solutions of blood stains from those of other colored fluids is by the use of the spectroscope. The peculiar spectra produced by the passage of light through solutions of blood were noticed by Hoppe in 1862, and were suggested by him as a means of medico-legal research. Stokes, in 1864, and Sorby, Lethby, MacMunn, and others have added largely to our knowledge of this subject.

The coloring matter of fresh blood is known as hæmoglobin, and, according to Preyer, it contains nearly all the iron of the blood. By the action of reagents, such as acetic, tartaric, and citric acids, the *bright red* of fresh blood becomes changed to *brownish red*, known as hæmatin. This is a permanent chemical change. The same change of hæmoglobin into hæmatin takes place when blood has been kept for a long time. The fresh blood stain is bright red (hæmoglobin); the old stain is brown (hæmatin). Hæmoglobin and hæmatin are each capable of existing in two states of oxidation, each state producing in the spectrum its own characteristic absorption bands. If a blood stain is kept in a damp place the hæmoglobin is rapidly changed into hæmatin, or both hæmoglobin and hæmatin may be decomposed. But if the stain is kept dry, it becomes in time of a brown color. This change is hastened if the stain is exposed to a strong light. This brown coloring matter is methæmoglobin, which Sorby regards as peroxidized hæmoglobin. This alteration is much more rapid in an atmosphere containing coal gas, or a trace of sulphurous or any other weak acid. The change is also very rapid when a stained garment is worn next the skin, as the acid perspiration hastens the change. If the color of a blood stain be a bright red it is evident that it is recent, but if it be brown it is not necessarily an old stain. When fresh blood, or a solution from a recent stain, is placed before the slit of a spectroscope, two dark absorption bands are seen between the Fraunhofer lines D and E, the line near D being darker, narrower, and more sharply defined than the other (Sp. 1-1, Fig. 609). If the strength of the solution is increased the bands grow wider and the orange and blue are gradually obliterated. If the strength of the solution is diminished the line near E first fades away and then the line near D also soon disappears. If the stain has been changed to brown by the action of the air the coloring matter becomes peroxidized, and the solution then gives a single band between the positions of the two above described (Sp. 2-2, Fig. 609). The coloring matter giving the single band is known as methæmoglobin.

Alkaline Hæmatin.—Make a saturated solution of carbonate of potash in alcohol and pour a few drops of blood or solution from a recent stain into the solution. The color immediately changes, and when examined in the spectroscope a broad, lightly shaded band is seen covering Fraunhofer's line D. Caustic potash and caustic soda in alcohol when added to blood give the same spectrum, but different from that produced by aqua ammoniæ or by carbonate of potash. It consists of three bands, one in the red, the other two like the bands produced by fresh blood. In the addition of a reducing agent the spectrum of reduced hæmatin appears, consisting of two bands similar to the bands of fresh blood, but removed farther from D toward the blue part of the spectrum.

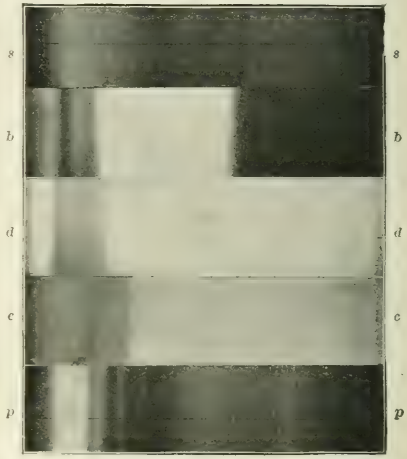

FIG. 608. *s s*, Solar spectrum; *b b*, human blood spectrum; *d d*, didymium spectrum; *c c*, carmine spectrum; *p p*, potassium permanganate.

In Fig. 608 are shown at *s–s* the Fraunhofer lines of the solar spectrum. Below are shown the spectra of different colored fluids: *b–b*, human blood; *d–d*, nitrate of didymium, of a faint pink color, in solution with lines similar to those of blood but easily distinguished from them; *c–c*, carmine solution, and *p–p*, the spectrum of a solution of permanganate of potash with three dense lines and one very faint in the red. All the spectra were photographed on the same scale. All the fluids were illuminated by the electric light, and the right half of the spectra shows carbon and other lines produced by the flame of the carbon electrodes. Many more might be presented, but these specimens are given to illustrate the marked distinction, as shown by the spectroscope, between blood and other colored fluids.

Instruments for Spectrum Analysis of Blood Stains.—As the absorption bands produced by colored fluids are broad and not very sharply defined, an instrument of much less dispersive power than that used for colored flames is required. The microspectroscope made by R. and J. Beck, to be attached to the microscope instead of the objective, is very useful when the quantity of colored matter is considerable, as it allows the use of the micrometers in the eyepiece of the microscope to mark the

Blood Stains.

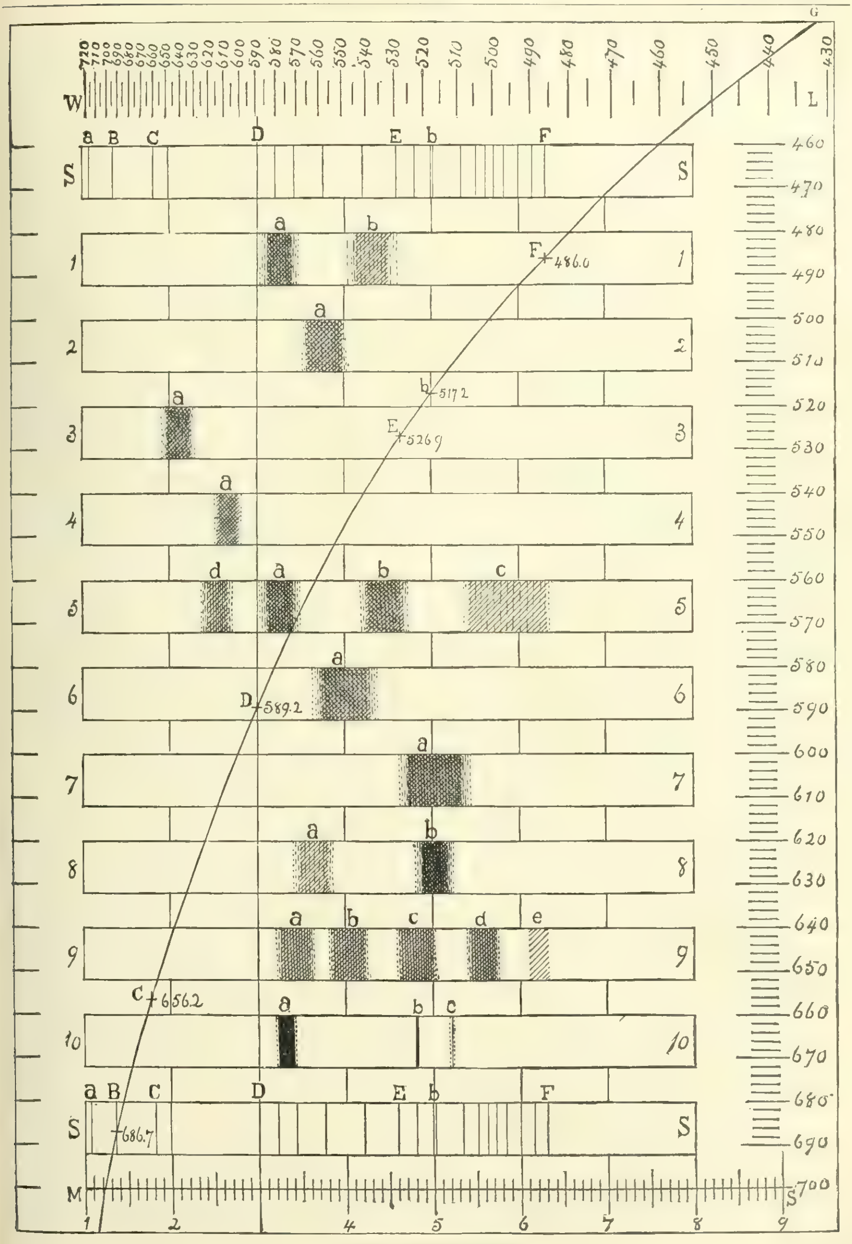

FIG. 609.—Spectrometry of Blood.

position of absorption bands. When the quantity of coloring matter is small, or a mere speck of clot moistened on the slide is to be examined and tested, the objective, as low a power as practicable, is to be retained in the microscope and a microspectroscope inserted instead of the eyepiece. The Sorby-Browning microspectroscope in place of the eyepiece has been used for this purpose, but with this instrument it is very difficult to get the light from the clot centred in the slit of the spectroscope.

The microspectroscope made by Zeiss, of Jena, is inserted in the microscope in place of the ordinary eyepiece, and the direct vision prism can be turned to one side and by opening the slit the object on the stage of the microscope can be found and focussed; then when the prism is replaced the absorption bands are seen. It has also a side stage where a comparison specimen of blood or other fluid can be placed and its absorption bands compared with those of the object on the stage. It also has a micrometer scale illuminated by a side light by which the positions of the bands can be measured and records made, as illustrated in Fig. 609, M, S. With such a microspectroscope, under favorable circumstances, the absorption bands can be seen in a single corpuscle of perfectly fresh blood, but not in a single corpuscle from a dried stain. But the bands can often be clearly seen in a speck of clot $\frac{1}{400}$ or even $\frac{1}{1000}$ of an inch in diameter when moistened with normal salt solution or with glycerin water. In the spectrum analysis of blood stains, careful comparison with known solutions of blood treated in the same manner may be made by placing the known solution before the comparison prism, as in the Zeiss instrument, when any variation between the spectra placed side by side can be readily determined.

For recording observations and results obtained it is important to determine the wave length of the centre of every absorption band, noting the conditions and treatment of the stain by which it was obtained. To obtain wave lengths, each microspectroscope must have a micrometer of its own, with a scale of wave lengths carefully adjusted to the prisms and lenses used. Such tables and scales are shown in Fig. 609. Spectrum S–S shows the positions of the principal Fraunhofer lines of the solar spectrum. All the spectra in this figure or plate are drawn to the same scale, and the line D–D, from the top to the bottom of the page, is used as a starting point from which measurements are made and by which the position of the micrometer is adjusted. The didymium line, *b*, in Sp. 10–10, is used in the same manner for fixing the position of the scale when artificial light is employed.

The micrometer measurements may be reduced to wave lengths by means of an interpolation curve, shown at B, C, D, E, *b*, F, G, constructed as follows: At the right hand is a scale of equal parts, numbered from 460 to 700. These numbers represent in millionths of a millimetre the length of all the waves of light which require to be considered in the analysis of blood stains. Across vertical lines, drawn through the Fraunhofer lines in the spectra S S, S S, horizontal lines are drawn from the scale at the right side of the plate at positions corresponding with the known wave lengths of the Fraunhofer lines.

$a = 718.5$ $C = 656.2$ $E = 526.9$ $F = 486.0$
$B = 686.7$ $D = 589.2$ $b = 517.2$ $G = 430.7$

Through these points of intersection of the vertical and horizontal lines the curve B F is drawn. Then from points in this curve opposite to the numbers 460, 470 to 700, vertical lines are drawn, and these enable us to draw the scale W L, which serves to determine the wave length of any band measured by the micrometer M S.

The position of absorption bands thus determined may be recorded, and at any future time compared with the records of other observers.

In Fig. 609, Sp. 1–1, at *a* and *b*, are shown the absorption bands of normal blood drawn in their relations to the Fraunhofer lines as seen in the Sp. S–S, and their true positions on the scale of wave lengths, W L. The band *b* is seen to be broader and paler than the band *a*. In Sp. 8–8 are shown the absorption bands of an ammoniacal solution of carmine, where *a* is shown to be paler than *b*, and also that *b* has a wave length 517 at its centre, while the band *b* in the spectrum of blood 1–1, *b*, has the wave length 538.*

The Sp. 9–9 shows the positions of the five bands in a solution of permanganate of potassa. In Sp. 5–5 the bands *a b c* are produced by a solution of alkanet, where the band *a* is almost exactly like *a* in the blood spectrum 1–1, but *b* and *c* are different. If a little alum is added to the solution of alkanet, the band *d* appears, while *a b* and *c* remain unchanged; if alum is added to a solution of blood, both the bands disappear. At *a*, in Sp. 2–2, Fig. 609, is shown the band of reduced hæmoglobin produced when hydrosulphate of ammonia is added to a solution of normal blood.

Other reducing agents produce the same effect. One of the best is made by dissolving equal parts of tartaric acid and double sulphate of iron and ammonia, and then adding a little aqua ammoniæ.

An ammoniacal solution of tartrate of protoxide of tin may be used as a reducing agent. It is prepared by adding tartaric acid to an aqueous solution of the protochloride of tin, and neutralizing the solution with ammonia. The acid should be added in such quantity that after over-saturation by ammonia no precipitate is formed, but a clear solution remains.

Sulphide of sodium is highly recommended by Preyer as a reducing agent. Dr. Beale recommends, as a deoxidizing solution, protosulphate of iron, with sufficient tartaric acid added to prevent precipitation by alkalies. A small quantity of this solution, made slightly alkaline by ammonia or carbonate of soda, is to be added to a weak solution of blood in water.

At *a*, in Sp. 3–3, is shown the band peculiar to acid hæmatin, wave length 640.

At *a*, in Sp. 4–4, is the band of alkaline hæmatin, wave length 605.

At *a*, Sp. 6–6, is shown the absorption band of a solution of fuchsin, wave length 548.

At *a*, Sp. 7–7, is the band produced by a solution of eosin, wave length 517. All absorption bands vary in intensity and in breadth as the strength of the solution varies, but the centre of the band remains stationary.

At *a b c*, in Sp. 10, are shown a series of beautiful bands produced by a solution of sulphate of didymium.

This remarkable substance, of a faint pink hue, in solution almost as colorless as water, gives a broad absorption band *a*, central at a wave length of 575 millionths of a millimetre, extending from 571.5 to 578. The line *b* is very sharply defined at wave length 523 of the same scale. This substance serves as an index to fix the position of the micrometer scale when using artificial light.

Besides the substances mentioned above, some other red solutions give absorption bands somewhat similar to that of blood, but with careful manipulation and appropriate tests they may be certainly distinguished from blood. The coloring matter of the petals of the red variety of *Cineraria*, a variety of chlorophyll, gives two bands somewhat like that of blood, but the micrometer readily shows that they occupy different positions on the scale of wave lengths. Add ammonia, and the blood bands remain unchanged, while those of the *Cineraria* solution are altered or completely destroyed.

A solution of *cochineal in alum* gives the bands *a b*, Sp. 8–8, Fig. 609, differing little from those of fresh blood. Add ammonia, and in both solutions the bands become more intense. Now add excess of boric acid; in the solution of cochineal the bands shift toward the blue end of the spectrum, while in that of blood they remain unchanged.

The other reds likely to be confounded by the unpractised eye with blood are *lac-dye*, *alkanet*, *madder red*, and *munjeet*, dissolved in each case *in alum*.

But if the spectra be carefully examined side by side with blood, or their wave lengths determined on the scale by their positions seen on the micrometer, it will be apparent that the bands produced by these bodies are not the same, either in position or in character. Further, none of them will stand the action of ammonia, while they are all bleached with sulphite of potash, which has no action on blood. In the examination of *a mixture of magenta and blood*, the magenta bands may entirely mask those produced by blood. The various blood spectra may, however, be easily obtained unmixed by adding to the solution a trace of sulphite of soda, which completely removes the magenta coloring matter, but leaves the blood untouched.

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* The scale of wave lengths are in millionths of a millimetre.

All the supposed fallacies disappear if we successively obtain the various blood spectra with the reagents already described.

Examination of a Recent, or Comparatively Recent, Blood Stain on a White Fabric.—(1) If you can detach a portion of the blood, do so; but if this is impossible, cut out a small piece of the stained fabric, and soak it for about ten minutes in a few drops of cold distilled water in a watch glass. Then squeeze the colored fluid out and set it aside for a short time, so that any insoluble matters may be deposited. Provide a glass cell about one-eighth of an inch in diameter and half an inch high, which may be made of a section of barometer tubing cemented to a slide with gutta-percha, with a diaphragm of tin foil between the slide and the end of the tube. With a fine drawn pipette introduce the red fluid into this cell, and place it on the stage of the microscope with an objective of low power, and illuminate with sunlight or other strong light, when, with the microspectroscope in place of the eyepiece, if the solution is blood the characteristic absorption bands will readily be seen. If there is a sufficient quantity of the solution, several tubes may be filled. If the tube contains any sediment, it may be laid to one side until the solution is clear. The objective should be focussed near the top of the tube, a little below the surface of the fluid. If the blood is tolerably recent, the spectrum of oxidized hæmoglobin with its two well-defined absorption bands in the green will be apparent, as shown in Fig. 609, Sp. 1–1. If such a spectrum is obtained, it is evident that it has been very little changed by exposure, and that it is probably of recent origin. If the spectrum contains two faint bands in the green, and an extra band in the red, it indicates that the stain has undergone a change. Now add a trace of ammonia to the solution in the tube, stirring it with a platinum wire, when you will obtain two bands in the green and none in the red.

(2) To a second tube of the suspected solution add, first, a very little ammonia, and then a small quantity of Rochelle salt. With this no change will be produced in the spectrum, the ordinary bands being visible as before Now add to the liquid in the cell a piece (about one-fortieth of an inch in diameter) of the double *sulphate of protoxide of iron and ammonia*; stir the solution with the platinum wire, with as little exposure to the air as possible. Cover the cell with a piece of thin glass. The two bands seen previously will have disappeared, and will be replaced by a single intermediate band, fainter but broader than either of the other two, Sp. 2–2, Fig. 609. This is the spectrum of reduced hæmoglobin The same effect will be produced by a trace of solution of sulphide of ammonium

The specimen of hæmoglobin thus reduced may be again and again oxidized by exposure to the air and vigorous stirring with the platinum wire It can be again deoxidized by further addition of the iron salt, or by sulphide of ammonium, if that was previously employed for deoxidation

This deoxidation and reoxidation of the hæmoglobin is a very characteristic reaction, and serves to distinguish blood from most other substances If the solution of blood is merely covered with thin glass and kept for some time in the cell, the reduction of the hæmoglobin will be effected spontaneously, and without the addition of any reagents

A question may arise here, whether this spectrum can possibly be due to iron. The question is at once answered by the fact that hydrosulphide of ammonium produces the same result, as also does the tin solution described on page 78, only that it acts more slowly than the iron salt.

(3) Add to another portion of the suspected solution, in a cell, a minute fragment of *citric acid*, stirring it thoroughly with a platinum wire. The acid will change the hæmoglobin into hæmatin. If previous to the addition of citric acid the two bands of oxidized hæmoglobin were visible in the green, they will disappear, and if the solution is tolerably strong a faint band will be visible in the red (Sp. 3–3, Fig. 609). Add now an excess of ammonia, by dipping the plantinum wire into the ammonia solution and stirring the moistened wire immediately into the liquid in the cell. The band in the red, if present, will now disappear, the original bands either not being restored at all or restored only to a slight extent. This is a most important change to note, since it shows that the acid has effected a permanent change in the original coloring matter of the blood. Add now to the solution in the cell a very small particle of the double sulphate of iron and ammonia, and cover the liquid over immediately with thin glass. Remove the excess of liquid with blotting paper, and in order to exclude air it is advisable to fix the glass cover on the cell with gold size. Turn the cell over and over again, for a few minutes. In cold weather the process of oxidation is slow, and even a quarter of an hour may elapse before it is complete. By this means the hæmatin will be reduced, and two well-marked bands will be seen, the one nearest the red being the first to appear, and both being a little more distant from the red than the bands of fresh blood. If the solution be very turbid, the precipitate may be allowed to collect on the side by keeping the tube for a short time in a horizontal position. Preserve and mark the specimen for further examination if necessary.

By exposing this solution of deoxidized hæmatin to the air, assisted by vigorous stirring, we may often succeed in bringing back again not only the oxidized hæmatin band, but also the bands of oxidized hæmoglobin.

(4) Lastly, add to some of the liquid under examination a small quantity of *boric acid*. If the solution be blood, no immediate change will be observed in the position of the bands. The above-mentioned method of examining blood stains of recent origin requires some modifications in special cases.

Old Blood Stains or Blood Stains on Colored Fabrics.—If blood stains are old, the coloring matter will probably be found to be scarcely at all acted on by cold water. Either citric acid or ammonia must then be used for dissolving it. If the fabric be white, ammonia should be employed in preference to citric acid, but if it be colored, test, first of all, which of these two reagents has the less action on the dye-coloring matter, and then use that one, for the purpose of dissolving the blood, which acts less on the color of the cloth. To determine this, place a little of the fabric in two watch glasses and apply a solution of ammonia to one and a solution of citric acid to the other In general, ammonia should be used in preference to citric acid. but in the case of red fabrics ammonia will generally dissolve so much of the dye stuff that subsequent investigations with the colored solution are rendered much more troublesome and complicated. Hence, if the stain be found on scarlet cloth or other red material. citric acid should be used as the solvent. If the stain be found insoluble both in ammonia and in citric acid, then it should first of all be acted on with ammonia solution and a moderate heat afterward applied.

Proceed then with the solutions in the manner already described, examining them with the spectroscope both before and after deoxidation with the iron salt. The age of a stain does not in general interfere with the spectroscope test, as Mr Sorby has been able to discover hæmatin with the spectroscope after forty four years and others have done the same after thirty years.

The presence of mordants on various materials may necessitate occasional alterations in our proceedings. More particularly will this be the case if the stained fabric has been afterward wetted and the blood by this means to a great extent removed.

What blood remains on the cloth is then very likely to be incorporated with the mordant. In such cases a process such as the following should be adopted: Digest a portion of the stained cloth in dilute ammonia, and afterward squeeze out the liquid. Deoxidize the *thick, turbid, unfiltered solution* in the ordinary manner and examine it for the deoxidized hæmatin bands, using concentrated sunlight, or the lime-light if necessary.

It is to be remembered that in the case we are supposing the hæmatin is probably chemically combined with the mordant; hence filtration, or allowing the deposit to subside, is equivalent to removing most of the blood coloring matter. The turbidity of the liquid must be overcome in such cases, not by removing the deposit, but by increasing the intensity of the transmitted light.

Examination of Stained Fabrics that have been Washed after Staining, and the Treatment to be Adopted in the Examination of the Water that was used for Washing Them.—Hæmatin is a very insoluble body. Probably, therefore, after an article stained with blood has been washed in water, provided a sufficient time has elapsed for the change of the blood-coloring matter into hæmatin to be effected, enough will be left on the stained cloth to produce the spectra necessary for its identification. But it must be remembered that if the stain be perfectly recent, that is, before any of the hæmoglobin is converted into hæmatin, the whole of the blood may then be washed out by rinsing in cold water, and no trace be afterward found on the stained material. Hot water will not effect this removal of the blood like cold water, owing to its further action. Hence, if in a criminal case there is proof that an article has been washed in *cold water*, evidence as to the absence of blood stains is of little value; while if, after staining, the article was washed in *hot water*, the probability is there will be no difficulty in satisfactorily proving the real character of the stain. In many cases, after a stained fabric has been washed, the blood stain will be found spread over a considerable surface. Under such circumstances a large piece must be cut out, and digested with a proportionately large quantity of ammonia, or of citric acid solution, the liquid being concentrated afterward by evaporation at a gentle heat.

The water used for washing such materials may have to be examined. This can be done by concentrating the liquid, if necessary, and examining it in the usual manner If, however, it is found that there is any deposit in the water, it should be carefully collected, acted on with ammonia, and heat applied if the blood be insoluble in the cold solution.

If the recently stained fabric, however, be washed with *soap and water*, hæmoglobin will be rapidly converted by the action of the alkali into hæmatin. Soap and water, therefore, really sets the stain, and the probability is that, after washing, there will be little difficulty in detecting it on the fabric itself by the ordinary means. It may be necessary sometimes to examine the soap and water to see if it contains blood. This may be done as follows· Agitate the soap and water with ether and allow the mixture to stand until the ether has completely separated. Remove the ether with a pipette, and again and again shake the liquid up with ether until the aqueous solution is perfectly clear and free from soap This liquid must then be concentrated, and examined as usual for blood

Examination of Stains on Leather.—Blood stains on leather, or upon any body containing tannic acid, require special management on account of the precipitation of the coloring matter which is more or less certain to result. Proceed as follows.

(*a*) Cut off a fine shaving from the stained portion of the leather, so that there may be as much blood and as little leather as possible on the shaving. Bend this shaving so that the side that is stained may be brought into contact with a little water placed in one of the experimental cells, while the leather side of the shaving is not wetted. In this manner solution of the blood will probably be effected, and enough coloring matter obtained for experiment.

Mr. Sorby points out, however, that when a drop of blood falls on leather, the serum soaks into the leather, and leaves the blood corpuscles on the surface. If the leather be then washed, it would probably be impossible to obtain the blood spectra by the method just described. The following process, recommended by Mr. Sorby, has been found to work satisfactorily:

(*b*) Digest, for a considerable time, a portion of the stained leather in a mixture of one part (by measure) of hydrochloric acid and fifty of water. This will effect a solution of the mixed compound of the blood-coloring matter and tannic acid. Pour off the acid liquid, but do not filter it. The solution may appear almost colorless, or of a slightly yellow tint. Add to this an excess of ammonia, when the color will become either a pale purple or a neutral tint, the tint shade being considerably intensified on the addition of the ferrous salt and double tartrate, which are now to be added. The solution is then to be examined in an experimental cell, using a sufficiently intense light, such as the lime-light, or direct sunlight, to penetrate the turbid solution. Under these circumstances the spectrum of deoxidized hæmatin will be seen. If the liquid be too turbid to allow even a direct ray from the sun to be passed through it, allow the cell to remain for a few minutes in a horizontal position so that a little of the deposit may subside, although if this can possibly be avoided it is desirable to do so, because it will be found that the removal of the deposit at the same time destroys the intensity of the spectrum, proving that the greater part of the hæmatin under these circumstances exists as a compound insoluble in dilute acid.

Before commencing the experiment with the stained portion of the leather, it is advisable to make out clearly how large a piece of the unstained leather may be treated with a given quantity of the acid without producing too dark a solution, and to take care afterward not to employ a larger piece of the stained portion of the leather than is justified by these trial experiments.

Blood Stains on Earth and on Clothes soiled with Earthy Matters.—The stained earth is to be carefully collected and digested in a considerable quantity of ammonia. This is to be poured off, concentrated by evaporation, and the spectroscopic experiments conducted as usual on the turbid solution, an intense light, such as the lime-light or direct sunlight, being used for the purpose, in the manner already described. A similar process should be adopted in examining stained fabrics soiled with earthy matters. This is important to note, inasmuch as the coloring matter in a solution of blood will be found to be completely carried down by earthy matter when shaken up with it.

General Precautions to be Observed in Conducting Micro-spectroscopic Observations.—We now add a few words of general advice and a few precautions necessary to be observed in examining blood stains by the spectroscope.

(1) If the fabric on which the blood stain occurs be colored, always examine the spectrum produced by the coloring matter alone, taken from unstained portions of the fabric. Further, it is well to put a little blood on an unstained portion, and to examine its spectra when dry, and thus fully determine, before commencing experiments on the stained portion, any possible interference in the blood spectra resulting from the presence of such coloring matter.

(2) On no account decide that an observed spectrum from a suspected stain is due to blood unless it *exactly* coincides with bands produced by a known solution of blood of equal strength treated in a similar manner and examined side by side. It is advisable to have several tubes of the deoxidized hæmatin of different strengths for purposes of comparison These solution are best

kept in hermetically sealed tubes, so as to have them at hand whenever they are needed.

(3) In all cases examine the spectra both by daylight and by artificial light. We prefer artificial light for general work, but in every case it is advisable to try both means of illumination. Direct concentrated sunlight, or the lime-light, should be tried whenever the solution is thick and turbid.

(4) Never be content with observing a single spectrum of blood. Remember, further, it is often impossible to obtain the unaltered blood spectrum. Hence never satisfy yourself that a stain is not blood until you have failed to obtain all the spectra produced by the appropriate reagents.

(5) If the liquid under examination be *too strong*, too much light will be cut off by the solution, and the absorption bands will be in this way obscured. If the solution be *too weak*, the bands will be too faint, and so likely to be overlooked. Practise in this matter to obtain the happy medium. Never (if possible) be satisfied with a single examination.

(6) Use extremely minute quantities of the several reagents. Hæmatin produced by an acid is not very soluble in a strong solution of citrate of ammonia. If you add too much protosulphate of iron the precipitate produced so obscures the field as to mask the absorption bands.

(7) Adjust the width of the slit during the spectroscopic examination. All absorption bands are best defined when the slit is very narrow, while, if the bands are very faint, they will often be best seen at the very moment when the slit is being completely closed.

(8) Remember that, with our present knowledge, the spectrum microscope affords no information whatsoever as to whether the blood is from man or beast, nor from what class of animals it is derived; nor, if it be human blood, does it enable us even to hazard a conjecture as to the locality of its origin. 9. Lastly, unless the stain is bright red—an appearance which can be noted only on white or nearly colorless fabrics—never venture an opinion as to the probable age of the stain.

Of the certainty of this method of research, Mr. Sorby says (*Medical Press and Circular*, May 31, 1871): "I unhesitatingly say we can distinguish blood (by the microspectroscope) from all other animal and vegetable coloring matters."

5. MICROSCOPICAL EXAMINATION OF BLOOD STAINS.—Besides the fluid portion of blood, certain organized bodies are found, called corpuscles, consisting of two varieties, the white and the red. In the higher animals the red corpuscles are the smaller but the more numerous, while the white corpuscles are rather larger and somewhat granular in structure and of a spherical form. The red corpuscles are circular, biconcave discs, of soft viscid matter, mostly soluble in water, but only very slowly dissolved by serum and the fluid part of the blood. The outer part of the red corpuscles is of firmer consistence than the interior, especially in the older corpuscles, but there is no special envelope or cell wall. By the action of water the coloring matter may be dissolved out, leaving the form of the corpuscle but little changed, except that it becomes nearly spherical.

When blood is spread upon glass, or any hard nonporous substance, the corpuscles adhere and retain their diameters unchanged, but when blood dries in a clotted mass, the red corpuscles shrink and often assume a crenated or stellate form.

If the stain to be examined is a mere film on a steel instrument or other smooth, hard substance, as glass or varnished wood, it may be laid on the stage of the microscope, and with a quarter or one-eighth inch objective, with Beck's patent illuminator above, the light of a lamp may be reflected down through the objective. In this manner the stain may be examined as an opaque object.

By this method the writer has succeeded in recognizing and measuring blood discs, magnified fourteen hundred diameters, on the blade of a knife which had lain in the forest, covered with leaves, through two winters. Generally blood stains form a mass too thick to be examined by this method, yet even then the corpuscles contracted to dimensions much below normal may be recognized as blood by this method of examination.

If the stain is in the form of shining scales, or if it is on cloth, leather, or any porous substance, it may be picked off with a needle or pointed instrument, and the dust or particles of clot received upon a glass slide and moistened with a suitable fluid to separate the corpuscles and restore them to their normal dimensions.

Fluids used in the microscopic examination of blood corpuscles should be such as will not destroy them, and such as will not increase or decrease their dimensions beyond their normal size. For this purpose a fluid should generally be used having the same specific gravity as blood serum, 1.028 or 1.029.

Robin's fluid consists of distilled water, to which is added chloride of sodium, one per cent., and bichloride of mercury, one-half of one per cent.

Roussin's Fluid.—Glycerin, three parts; sulphuric acid, one part; with water sufficient to reduce the specific gravity to 1.028.

Hayem's fluid consists of distilled water, with the addition of sulphate of sodium, two and one-half per cent.; pure chloride of sodium, one-half per cent., and bichloride of mercury, one-fourth per cent.

Professor J. G. Richardson employed water with the addition of common salt, three-fourths of one per cent.

Dr. Thad. S. Up de Graff, who was very successful in distinguishing the blood of man from that of the lower animals, employed water with bichloride of mercury, one-half of one per cent.

Many other microscopists use glycerin and water, mixed in such proportions as to give a specific gravity of 1.028.

Each of the fluids described has some advantage over the others. The fluids containing bichloride of mercury are not likely to be infested with fungi when specimens are kept for a length of time. Glycerin water interferes less with other tests which may be applied after the microscopic examination is completed; but in this respect it has no advantage over Richardson's salt solution.

Filtered serum from the blood of a frog may be employed in examining stains supposed to be from mammalian blood. Albumen of egg is also sometimes used.

In moistening blood stains with any fluid whatever it is to be remembered that the substance of the stain absorbing the fluid renders it more dense than it was when prepared; therefore, if the fluid employed has no greater density than blood serum there is no opportunity for the blood corpuscles of the stain to enlarge beyond their ordinary dimensions in normal blood. As yet no fluid has been described which will cause dried blood corpuscles to swell up to a greater diameter than the original fresh blood. When by the action of water the red corpuscle becomes spherical, its diameter is diminished.

When a blood stain is situated upon paper more of it remains on the surface than when the stain is upon cloth, and, after the paper is moistened, the film of blood can sometimes be detached from the surface in small scales or lumps. Mingled somewhat with filaments of the paper, and with molecular material, we find blood globules more abundant than in stains upon cloth. The form of the globules is also better preserved, and they are often seen in nummular masses, as in fresh blood, and we recognize the central depression and dentate borders characteristic of corpuscles of mammalian blood. These masses also preserve the color which distinguishes blood from all colored objects of vegetable or mineral origin.

Stains upon wood have characteristics similar to those of stains upon paper.

Stains upon woollen goods are somewhat more difficult to determine than those on cotton, linen, paper, or wood.

If we use the sulphate of soda solution for the examination of fresh stains (not more than six days old) upon iron or steel, the fibrin separates and leaves the corpuscles floating free in the liquid, and the clot shows the characteristic fibrillar arrangement. We find also the white corpuscles either isolated or entangled in the clot. The white corpuscles are no less characteristic than the red by their size, form, finely granular appearance, and nuclei, which appear near the centre, brought into view by the sulphate of soda solution. This solution acts upon the white corpuscles almost as quickly as pure water, but causes them to swell less. The characteristics which distinguish white blood globules from pus should be noted whenever there is a possibility of finding the two together, which is not common in legal cases.

If blood stains have been deposited on rusty iron or steel, or have remained long on such instruments even if not rusty, the glycerin solution is much to be preferred in their examination, as it does not act upon the metal; while sulphate of soda or any of the acid solutions cause the deposit in the preparation of dark granules formed of a salt of iron.

The fine dust obtained by scratching a stain with a needle point or by crushing a large particle picked off from a shining clot, should be covered with a circle of thin glass, and a drop of one of the solutions described above should be allowed to run under the cover. If the stain is recent, it will be in a condition for examination in a few days, or in some cases in a few hours. If the stain is old, over six months, a much longer time is required to soften it. If the object is only to recognize blood corpuscles when the dust-like particles have been softened, the fluid may be drawn away by touching one side of the cover glass with blotting paper, at the same time placing a drop of a staining fluid—as a watery solution of eosin or iodine—on the opposite edge of the cover. After two or three minutes the colored fluid may be withdrawn in the same manner, and salt solution or glycerin water allowed to take its place, when the blood corpuscles, if any exist, will be easily distinguished, and may be measured by the use of the micrometer. Where a stain on paper, leather, or blades of grass is so thin that no particles of clot can be removed, Prof. F. B. Wyman, M.D., hardens the stain in formalin or in equal parts of alcohol and ether for five or ten minutes, then stains in a watery solution of eosin, dehydrates with alcohol, clears in oil of bergamot, and mounts the paper, leather, or grass in Canada balsam as ordinary sections of tissue are mounted. The blood corpuscles of the stain are then clearly seen and can be measured.

If the stains are not very recent, provision must be made to prevent evaporation of the fluid used to soften them. Take a glass slide with a circular excavation in the middle, called a "concave centre," and moisten it around the edges of the cavity with glycerin. Thoroughly clean a glass cover an eighth of an inch or more larger than the excavation, lay it on white paper, moisten the centre with the glycerin solution (sp. gr., 1.028), dropping into the solution so placed the dust obtained from the stain, then invert the slide upon the thin glass cover in such a manner that the glycerined edges of the cavity on the slide may adhere to the margins of the cover; turn the slide face upward, and examine with the microscope. In the fine dust thus moistened, isolated red and white blood corpuscles will often be seen immediately. If not, lay the slide face downward on a suitable support, and examine from day to day until the corpuscles become visible and cease to enlarge. They cannot exceed their normal size when treated by this method.

Prof. Joseph G. Richardson, M.D., made a minute dot of glycerin, about the size of this period (·), on a thin glass cover, and pushed into it a particle of suspected blood clot, the smallest that can be seen by the naked eye, one-thousandth or one-five-hundredth of an inch in diameter, receiving the cover on the concave slide as described above. By this method he obtained a strong solution of the coloring matter of blood, in which the absorption bands peculiar to blood could be seen, if blood was present in the stain; and by a little practice the bands may be modified by the addition of sulphuret of sodium, as advised by Preyer and Sorby.

By a similar method, using a little more material on a cover glass moistened with a very small drop of three-fourths-per-cent. salt solution, he was able to see, first, the absorption bands of blood with the microspectroscope, then, turning the slide so as to drain off superfluous fluid, and using the microscope with a magnifying power of about two thousand diameters, he was able to see and measure both white and red blood corpuscles, so as to distinguish human blood from the blood of the ox, pig, horse, or sheep.

In examining a slide prepared by either method above mentioned, if the material is blood, we first observe that the edges of the solid particles gradually become translucent and the fluid around assumes a reddish-yellow color, showing that the coloring matter is soluble. In this condition of the preparation by use of the microspectroscope the characteristic absorption bands of blood will be seen.

After a little time, if the amount of fluid applied be sufficient, the solid particles are softened, and, as they swell up, yellowish-white corpuscles with a slightly granular structure are seen; these are the well-known white blood corpuscles, which, with a magnifying power of one thousand diameters or upward, may be distinguished from other organized structures of either animal or vegetable origin. After longer maceration the characteristic red corpuscles of blood, with smooth and sharply defined edges, begin to appear, and after a time are found floating free in the fluid under the cover glass. If the stain is mammalian blood, some of the corpuscles will be clearly seen as biconcave discs with a light centre and a dark edge or border. If any doubt remains in regard to the nature of these corpuscles, it may generally be resolved by the use of a higher magnifying power. Grains of pollen may be generally distinguished by a roughened edge, or by small points on the surface. Spores of fungi are often found mixed with blood stains, but in general the texture is different from that of blood. Occasionally the biconcave structure of red blood corpuscles can be distinguished, as a slight motion causes some of them to roll over as they move across the field. Unicellular algæ, often seen in wet preparations, may be distinguished by the granules which they contain, having a greenish-brown or reddish color. These are grains of chlorophyll. Spores of fungi growing in fluids have generally, if undisturbed, some systematic arrangement not found in the positions assumed by blood corpuscles.

Erdmann records a case (*Zeitschrift für analyt. Chemie,* ii., 1862, and *Gazette Hebdomadaire,* quoted in *Edinburgh Medical Journal,* October, 1862, p. 370) which shows the importance of employing more than one kind of test in examining stains supposed to be blood. "The only trace of an assassination at Leipsic was a brownish stain found at the spot where the crime had been committed. Under the influence of rain, the stain had assumed the appearance of coagulated blood. An aqueous solution of this stain furnished a reddish fluid, which gave with tannin, with ferrocyanide of potassium, and with Millon's solution,* the same chemical reaction as the aqueous extract of dried blood. Examined under the microscope, the brown matter was found to contain some corpuscles very similar to those of blood. But Erdmann having failed to discover crystals of hæmin, conceived doubts as to the value of the other characters, and repeated with great care the microscopical examination. He then discovered that the bodies supposed to be blood globules were the spores of algæ called *porphyridium cruentum,* on account of the resemblance of its spores to blood corpuscles."

This blood-colored gelatinous alga, *porphyridium cruentum,* growing upon moist ground, is of doubtful occurrence in the United States (*Am. Quar. Mic Journ.*, April, 1879). Thudichum, in "Tenth Report of Med. Officer to Privy Council," 1867, p. 216, mentions a red, gelatinous mass, growing upon a human thigh-bone, which was macerating at St. Thomas' Hospital. The glass vessel in which it was macerating was similarly covered. The microscope showed the red material to consist of minute cells in a gelatinous mass, with which larger green cells were interspersed. The water filtrated from them contained a number of minute bodies in suspension. It was red, and gave a spectrum very similar to that of blood. The plant in question is called by Thudichum red saprophytes.

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* Millon's solution is a strongly acid (nitric and nitrous) solution of proto- and pernitrate of mercury, made by dissolving metallic mercury in its weight of strong nitric acid with the aid of heat.—Micrographic Dictionary.

To avoid mistaking algæ or other organized bodies for blood corpuscles, the guaiacum test, the hæmin-crystal test, and the spectroscope should be used.

The mammalian corpuscle, in its normal condition, is a delicate endosmometer, taking in or giving out fluid according to the relative density of the liquor sanguinis and contents of the corpuscle, allowing rapid variations within certain limits. Accordingly, the corpuscles may be either swollen, puckered, or shrunk into a variety of figures, flat, tumid, like a shallow circular or oval cup, stellate, notched, granulated, mulberry shaped, crescentic, angular, lanceolate, fusiform, or comma-shaped, or they may possess other figures defying description. In certain of the *cervidæ* the angular, crescentic, and lanceolate corpuscles are abundant. In connection with disease, deformed corpuscles are also found.

The recognition of blood stains, and the probable determination of the animal from which they came, depend on the use of solvents of the same endosmotic power as the serum of normal blood, and on the microscopic examination and measurement of the corpuscles having the normal form. In the blood of birds, fish, and reptiles having red blood discs of an oval or ellipsoidal form, it is sometimes possible, when they are standing on end or are distorted by drying, to see them as circular bodies. Time must therefore be allowed for the stains to be fully softened and the corpuscles to be isolated by the solvent before their origin can be decided. There are also some round corpuscles mingled with the elliptical, but they are too few in number to mislead a careful observer.

Stains formed by menstrual blood contain uterine and vaginal mucus mingled with cells of epithelium.

At the commencement of menstruation the linen is stained of a brown color, changing gradually to red. About the third day blood corpuscles are abundant, mingled with leucocytes and epithelium. The cessation of the courses is marked by the diminution of the red blood globules and the increase of leucocytes, rendering the flow more nearly purulent. Menstrual blood does not differ from any other blood, except that it is mingled with mucus and epithelium and an abnormal proportion of leucocytes, and that fibrin is almost entirely absent. The absence of fibrin is the most characteristic distinction of menstrual blood.

Blood Stains compared with Stains formed by Lochial Discharges.—Medical experts are often called, especially in cases of infanticide, to distinguish between stains of blood and those formed by the lochiæ. These stains are to be examined by the same methods as are available for stains of normal blood. In the lochial discharge, about six hours after delivery, we find about five leucocytes to one hundred red blood corpuscles. At the end of the first day only about one-third of the organized structures are red blood corpuscles. The leucocytes are nearly equal in number to the red corpuscles; pavement epithelium from the vagina is also abundant.

Among the cells are some spheroidal or somewhat polyhedral by reciprocal pressure, united in groups similar to the deeper layers of epithelium of the vagina or neck of the uterus. The liquid, more or less viscous or odorous, which holds these elements in suspension, is studded with grayish granules. On the second day the leucocytes increase in number and the red globules diminish, and little by little the lochiæ assume a russet tint, which on the third or fourth day passes into a grayish white or yellow.

From the fifth to the seventh day, varying in different subjects, the red corpuscles almost entirely disappear, and the leucocytes become decidedly granular. Pavement epithelium is still found, but less abundantly than during the preceding days. The epithelial scales are generally imbricated, coming off in patches. The gray molecules become more adhesive and abundant, and the fat granules diminish in number. Fibro-plastic, fusiform bodies without a nucleus, pale and transparent, are also found. This composition of the lochiæ continues without much change until the close of the flow. By these characteristics stains of lochial discharges can generally be distinguished from normal blood.

The blood of all animals contains certain organized structures called corpuscles. In all mammals except a few of the camel tribe the red corpuscles, which are the most numerous form, are circular biconcave discs of which there are in man from four to five million in each cubic millimetre of blood. Another form nearly spherical, called white corpuscles, of which there are about ten thousand to the cubic millimetre, have a nucleus and vary greatly in numbers in different stages of the digestive process and in different conditions of health.

It is with the red corpuscles that we are principally concerned in the study of blood stains.

In birds, fishes, and reptiles generally the red corpuscles are ellipsoidal and have a nucleus. By these differences of form it is easy, when using the microscope, to distinguish between the blood of a mammal and that of all other animals with two or three rare exceptions.

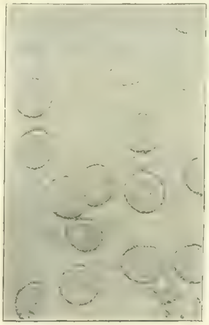
FIG. 610.—Blood of Lamprey Eel.

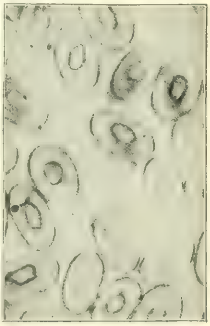
FIG. 611. Blood of a Snake.

In the blood of some of the camelidæ we find ellipsoidal corpuscles, but those can rarely if ever come into consideration in medico-legal cases. In the lamprey eel we find circular corpuscles with a nucleus; and these, again, are not likely to be mistaken for the blood of man or other mammal. On page 85 we give exact reproductions of photographs of the blood corpuscles of man and of the principal domestic animals, magnified 2,560 diameters, with a scale in which each division represents *half a micron* or about one-fifty-thousandth ($\frac{1}{50000}$) of an inch.

We thus see that when viewed by the high powers of the modern microscope wide differences are found between the blood of man and that of such animals as the pig, horse, ox, sheep, and goat.

In the blood of any single animal there are small and large corpuscles giving a considerable range between the smallest and largest in the same blood, while the general average of the corpuscles in man is greater than it is in any of the other animals whose blood is shown in the engravings. The accompanying table shows the range and general average, measured in *microns*, for man, dog, pig, horse, sheep, and goat:

TABLE SHOWING VARIOUS SIZES OF RED BLOOD CORPUSCLES (MEASURED IN MICRONS) IN MAN AND DOMESTIC ANIMALS.

Microns.	Man.	Dog.	Pig.	Ox.	Sheep.	Goat.
9.50						
9.25	1					
9.00	5					
8.75	3					
8.50	15					
8.25	32	..	2			
8.00	28	..	1			
7.75	51	5	5			
7.50	48	14	4			
7.25	10	21	6			
7.00	2	45	10			
6.75	4	56	15	1	1	
6.50	0	26	13	1	0	
6.25	1	11	19	0	0	
6.00	..	16	44	29	0	
5.75	..	5	19	16	0	
5.50	..	1	13	20	3	
5.25	..	1	17	71	9	
5.00	..	..	10	34	30	
4.75	..	..	6	19	38	
4.50	..	..	4	8	71	
4.25	..	..	4	1	26	2
4.00	..	..	3	.	12	11
3.75	..	..	5	..	3	94
3.50	..	..	..	..	7	63
3.25	..	..	..	..	..	24
3.00	..	..	..	..	..	6
Number of corpuscles*	200	200	200	200	200	200
Maximum	9.31	7.85	8.39	6.77	6.77	4.31
Minimum	6.39	5.46	3.85	4.46	3.85	3.16
Mean	8.01	6.87	6.07	5.44	4.75	3.69

* These numbers (two hundred in each column) include all between the number in the left hand column opposite to which they are placed, and the number next above.

In any specimen of blood we find corpuscles of varying size, but a remarkable uniformity in the average measurements of blood from animals of the same kind.

Some discrepancies appear in the tables of measurements of blood as given by different authors. The tables found in most works on physiology or on medical jurisprudence were made when the instruments employed and micrometers used were by no means as perfect as the microscopes and micrometers now available. The following table has been prepared with great care. The measurements, with two or three exceptions, were made by J. B. Treadwell, M.D., with a $\frac{1}{25}$-inch objective, magnifying about twenty-five hundred diameters linear, and a glass micrometer placed in the eyepiece. The blood was spread upon glass and quickly dried. The reduction and arrangement of the results as given in the table were performed by the writer of this article. The standard of measurement was a micrometer ruled by Prof. W. A Rogers, of Cambridge, Mass., and carefully compared with the standards procured at great expense by the United States Government.

MEASUREMENTS OF MAMMALIAN BLOOD.

Source of blood.	Number of corpuscles measured.	Mean diameter.	Minimum and maximum.	Range of averages by tens.	Range by twenties.	Range by fifties.	Range by hundreds.	Range by two hundreds.
5 men, ages 23 to 49 years	1,000	7.941	5.773 9.394	7.697 8.152	7.782 8.110	7.845 8.061	7.884 8.046	7.902 7.983
5 women, 18 to 55 years	1,000	7.927	6.350 9.287	7.825 8.152	7.787 8.026	7.873 7.993	7.901 7.963	7.913 7.950
3 infants, at birth, 1 male, 2 females	600	7.950	4.233 10.160	7.667 8.298	7.716 8.100	7.833 8.031	7.918 7.983	7.938 7.970
Boy, 8 years old	200	7.983	6.929 9.160	7.747 8.282	7.828 8.191	7.891 8.079	7.965 8.000	7.983
Man, 70 years old	200	7.916	7.005 9.236	7.658 8.121	7.662 8.105	7.768 8.028	7.852 7.980	7.916
15 persons, as above	3,000	7.938	4.233 10.160	7.658 8.298	7.662 8.191	7.768 8.079	7.852 8.046	7.913 7.983
Blood stains (human) restored	1,000	7.910	5.570 9.687	7.700 8.189	7.723 8.010			
25 dogs	2,500	6.918	4.618 8.931	6.138 7.352	6.445 7.305	6.523 7.258	6.673 7.198	
Guinea-pig, male, 3 months	200	7.476	5.849 8.390	7.231 8.698	7.309 7.659	7.249 7.634	7.393 7.559	
Woodchuck, female	200	7.280	5.387 8.467	7.043 7.528	7.112 7.374	7.215 7.351	7.279 7.282	
Muskrat, male	200	7.283	6.158 9.391	6.920 7.535	7.120 7.555	7.195 7.428	7.245 7.320	
2 rabbits, 1 white, 1 mixed	400	6.365	4.618 8.082	6.196 6.596	6.227 6.485	6.294 6.409	6.349 6.383	6.354 6.377
2 hares, 1 male, 1 female	400	5.764	4.618 7.120	5.367 6.080	5.377 6.049	5.604 5.863	5.733 5.779	5.756 5.772
Gray squirrel, 1 female, 1 male, 5 months	400	6.876	5.926 7.851	6.366 7.436	6.627 7.079	6.774 7.080	6.823 7.004	6.827 6.926
Red squirrel, female, 5 months	200	6.607	4.926 8.313	6.227 6.851	6.381 6.897	6.496 6.709	6.592 6.622	
Striped squirrel, female	200	6.753	5.387 7.697	6.573 6.981	6.647 6.901	6.701 6.815	6.747 6.758	
Red fox, male, 5 months	200	6.482	5.541 7.312	6.250 6.674	6.408 6.562	6.474 6.544	6.470 6.494	
Pig, 2 of 3 months, 1 of 2 weeks	600	6.101	3.849 8.391	5.418 6.520	5.757 6.466	5.880 6.246	6.028 6.169	6.069 6.144
Ox, 3 male, 2 female (one 1 day, one 3 months	1,000	5.436	3.916 6.774	5.150 5.703	5.296 5.622	5.345 5.543	5.347 5.482	5.406 5.461
Horse, 10 years	200	5.503	4.618 6.774	5.203 5.818	5.257 5.633	5.473 5.553	5.493 5.513	
Ass, 1 male, 1 female	400	6.293	5.003 7.697	6.018 6.566	6.138 6.539	6.201 6.377	6.219 6.376	6.259 6.326
Mule, 6 years	200	5.421	3.464 6.312	5.280 5.680	5.327 5.545	5.877 5.472	5.419 5.424	
Cat, 1 adult, 1 kitten, 3 weeks	400	5.463	2.617 6.774	4.311 5.780	4.361 5.676	5.268 5.573	5.419 5.522	5.431 5.495
Sheep, male, 15 days, female, 1 year	400	4.745	3.079 6.774	4.503 4.972	4.588 4.869	4.665 4.785	4.725 4.764	4.744 4.746
Goat, 1 male, 1 female	400	3.567	2.617 4.080	3.394 4.764	3.401 3.710	3.467 3.693	3.535 3.638	3.546 3.587
Mouse, house, common	200	6.038	2.309 7.004	5.772 6.281	5.891 6.200	5.990 6.094	6.037 6.039	
Mouse, house, long-tailed	200	6.099	4.618 6.696	5.857 6.258	5.968 6.208	6.063 6.143	6.089 6.109	
Mouse, field	200	5.095	4.080 6.928	5.733 6.041	5.803 6.995	5.814 5.967	5.891 5.919	
Rat, male	200	6.500	3.079 8.005	6.289 6.820	6.346 6.695	6.441 6.694	6.490 6.510	
Mole, male	200	6.216	4.618 7.697	6.095 6.435	6.080 6.339	6.131 6.293	6.175 6.258	
*Elephant	100	9.259	7.164 11.504	....	....	....	9.259	
Woman, 19 years, anæmia	100	7.346	3.464 9.237	6.674 7.605	7.012 7.628	7.177 7.515	7.346	
Child, 6 weeks old, starved to death	100	7.573	4.465 8.636	7.328 7.712	7.493 7.639	7.572 7.574	7.573	
*Human embryo, 143 grains, non-nucleated corpuscles	20	11.346	9.736 13.486	11.032 11.661	11.346			
*Human embryo, nuclei of nucleated discs	10	8.089	5.394 11.611	8.089				
A male cat, stupefied 5 hours by alcohol	100	5.489	4.772 7.235	5.327 5.680	5.426 5.846	5.479 5.498	5.489	

* Measured by M. C. White.

I was informed by Dr. Richardson that he measured from the outside of the dark border of the corpuscle on one side to the inner side of the dark border on the opposite side of the corpuscle. If we add one-fiftieth of the diameter for the remainder of the dark border we should obtain 8.036 microns, which is a trifle larger than the average given in the table. This difference may possibly be attributed to minute differences in the micrometers used, or it may be owing to what is known as the personal equation of the observer.

Professor Wormley, of the University of Pennsylvania, whose extensive and valuable measurements of blood corpuscles are published in the second edition of his work on "Microchemistry of Poisons," measured the whole of the dark border of the corpuscle. Professor Wormley used a one-tenth inch objective made by Beck, and a one-thirty-second inch objective made by Gundlach, mag-

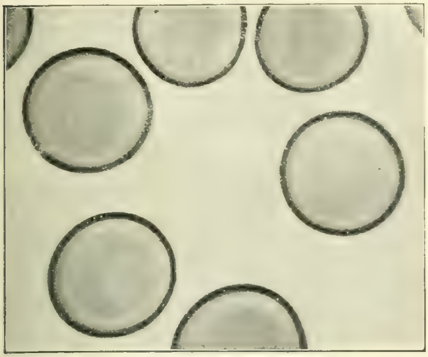

FIG. 612.—Human Blood (Red Corpuscles). × 2,560.

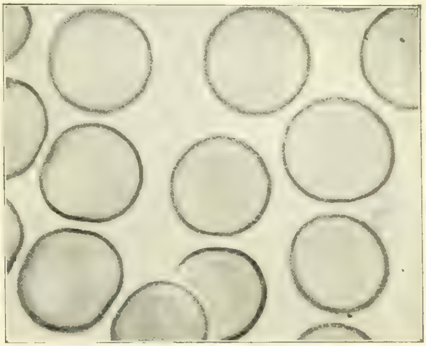

FIG. 616.—Red Discs of Dog. × 2,560.

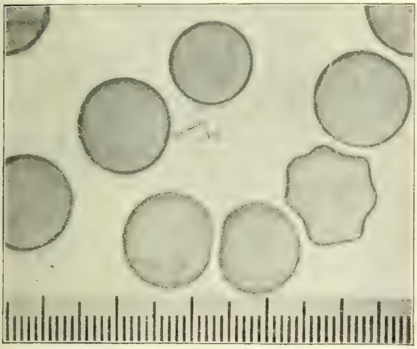

FIG. 613.—Blood of Pig. × 2,560. Division of scale, $\frac{1}{5000}$ inch.

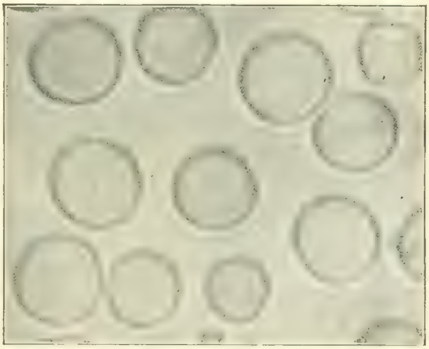

FIG. 617.—Blood of the Ox. × 2,560.

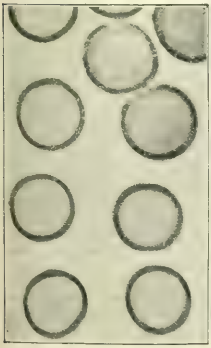

FIG. 614.—Blood of Sheep. × 2,560.

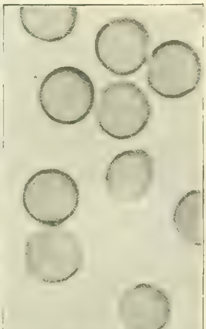

FIG. 615.—Blood of Goat. × 2,560.

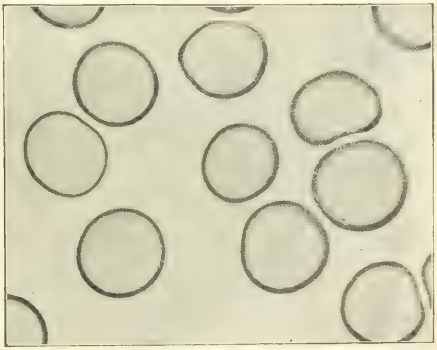

FIG. 618.—Blood of Horse. × 2,560.

nifying from 1,150 to 2,300 diameters. In the following table the measurements of Treadwell and Wormley are compared with the measurements made by Gulliver twenty-five years ago, and published by him in the "Proceedings of the Zoölogical Society of London" in 1875.

AVERAGE SIZE OF RED BLOOD CORPUSCLES, IN FRACTIONS OF AN INCH.

Mammals.	By Gulliver.	By Wormley.	By Treadwell.
Man	1-3200	1-3250	1-3200
Monkey	1-3412	1-3382	
Opossum	1-3557	1-3145	
Guinea-pig	1-3538	1-3223	1-3397
Kangaroo	1-3440	1-3410	
Muskrat	1-3550	1-3282	1-3487
Dog	1-3532	1-3561	1-3672
Rabbit	1-3607	1-3653	1 3984
Rat	1-3754	1-3652	1-3908
Mouse	1-3814	1-3743	1-4223
Pig	1-4230	1-4268	1-4163
Ox	1-4267	1-4219	1-4673
Horse	1-4600	1-4243	1-4614
Cat	1-4404	1-4372	1-4648
Elk	1 3938	1-4384	
Buffalo	1 4586	1-4351	
Wolf (prairie)	1-3600	1-3422	
Bear (black)	1-3693	1-3656	
Hyena	1-3735	1-3644	
Squirrel (red)	1-4000	1-4140	1-3847
Squirrel (gray)	......	......	1-3322
Ground squirrel (striped), chipmunk	......	1-4200	1-3762
Raccoon	1-3950	1 4084	
Elephant	1-2745	1-2738	
Leopard	1-4319	1-4390	
Hippopotamus	1-3429	1-3560	
Rhinoceros	1-3765	1-3649	
Tapir	1-4000	1-4175	
Lion	1-4322	1-4143	
Ocelot	1-4220	1-3885	
Mule	......	1-3760	1-4432
Ass	1-4000	1-3620	1-4036
Bat	1-4175	1-3966	
Sheep	1-5300	1 4912	1-5353
Ibex	......	1-6445	
Goat	1-6366	1-6189	1-7982
Sloth	1-2865		
Platypus (duck-billed)	1-3000		
Whale	1-3099		
Capybara	1-3190	1-3164	
Seal	1-3281		
Woodchuck	1-3484	......	1-3489
Musk-deer	1-12325		
Beaver	1-3325		
Porcupine	1-3369		
Llama Long diam	1-3361	1-3201	
Llama Short diam	1-6229	1-6408	
Camel Long diam	1-3123	1-3331	
Camel Short diam	1-5876	1-5280	
Red fox	......	......	1-3918

	GULLIVER.		WORMLEY.	
	Length.	Breadth.	Length.	Breadth.
Birds—				
Chicken	1-2102	1-3466	1-2080	1-3483
Turkey	1-2045	1-3598	1-1894	1-3444
Duck	1-1937	1 3424	1-1955	1-3504
Pigeon	1-1973	1-3643	1-1892	1-3804
Goose	1 1836	1-3839		
Quail	1-2347	1 3470		
Dove	1-2005	1 3369		
Sparrow	1-2140	1 3500		
Owl	1-1763	1 4076		
Reptiles—				
Tortoise (land)	1-1252	1-2216	1-1250	1-2200
Turtle (green)	1-1231	1-1882		
Boa constrictor	1-1440	1-2400	1-1245	1-2538
Viper	1-1274	1-1800		
Lizard	1-1555	1-2743		
Batrachians—				
Frog	1 1108	1-1821	1-1089	1-1801
Toad	1-1043	1-2000		
Triton	1-848	1-1280		
Proteus	1-400	1-727		
Amphiuma tridactylum	1-363	1-615	1-358	1-622
Fishes—				
Trout	1-1524	1-2460		
Perch	1-2099	1-2824		
Pike	1-2000	1-3555		
Eel	1-1745	1-2842		
Lamprey	Circular.	1-2134		
Nucleus	......	1-6400		

From these tables it is clearly shown that a careful microscopist would not be likely to mistake the blood of a goat, sheep, horse, ox, or pig for the blood of a human being; or that of any animal having blood corpuscles with an average diameter less than $\frac{1}{4000}$ of an inch or 0.0063 mm. (6.3 microns).

Concerning the possibility of distinguishing the blood of a dog from that of man, medical experts are in nowise agreed, a few contending that they can distinguish a recent stain of the blood of a dog from the blood of man, and they have successfully accomplished the task when put to the crucial test of experiment.

The late Col. J. J. Woodward, M.D., when testifying as an expert in the Hayden trial, at New Haven, Conn., in 1879, stated that he had measured twenty corpuscles from a young dog, forty from another, and fifty from a third, in which he found the averages of the corpuscles measured from each one of those dogs larger than the recognized average size of human blood corpuscles. In regard to these measurements Dr. Woodward stated in his cross-examination, by the state: "*I looked to find big corpuscles and I knew that the group around them would be large.*" The same expert has published measurements of the blood of other dogs so large that he inferred that there is no safety in attempting to state positively that a given stain is the blood of man and that it could not be the blood of a dog.

L. Perier has shown that the blood of new-born infants often contains giant corpuscles similar to the large non-nucleated corpuscles of the human embryo, and states that until recently these have not been considered as true red corpuscles.

He also states that these giant corpuscles have a tendency to collect together, and that in estimating average measurements it is important to examine all parts of the slide on which the blood is spread. L. Perier also says that he finds in the blood of infants many globulins nearly spherical, only about half the diameter of ordinary blood discs. If these globulins are not included in the measurement it will be easy to obtain large averages for the blood of infants.

Dr. R. U. Piper, of Chicago, finds that the blood corpuscles of new-born infants retain much of the character of pre-natal blood, and give an average diameter larger than that of the blood of adults. He also finds the blood of young puppies giving a larger average diameter than that of the blood of adult dogs, but these facts do not disparage the value of the microscope as a means of distinguishing the blood of man from that of full-grown dogs, especially if we can obtain for comparison authentic specimens of the blood of the particular man and dog with which a given blood stain is to be compared in a given case.

Dr. Thad. S. Up de Graff (in *The Microscope*, October, 1883) states that the red blood corpuscle of the dog resists the action of water and ruptures less readily than does the red corpuscle of human blood, because, as he thinks, the cell wall or border is thicker in the blood of the dog than it is in human blood.

By a careful study of the micrometric data from which the table of measurements by Dr. Treadwell was calculated I find as a general rule, to which there are some exceptions, that the blood corpuscles of young animals have a greater range (as Perier and Hayem have stated) from the smallest to the largest corpuscle, and a slightly larger average diameter, than have those of adults. This is shown in the case of a male pig, two weeks old, in the first table giving the range of two hundred corpuscles for that and other animals. The same is apparently true of the blood of females as compared with the blood of males. My own measurements of human blood of infants and adults, both male and female, tend to the same conclusions.

In the measurements given in this table the whole of the dark border was measured. The measurements were originally taken and recorded in parts of the American standard inch, which have been reduced to parts of a millimetre by reckoning 1 inch = 25.40098 mm. The measurements in the table are given in microns, 0.001 mm.

To secure a fair average two hundred corpuscles were generally measured, and often this number was measured from several animals of the same class. To show how large a number of corpuscles should be measured to obtain a fair average, the range of averages is given as computed by tens, twenties, fifties, and hundreds; also the range of averages of two hundreds as taken from the separate animals.

J. G. Richardson, M.D., of Philadelphia, during the progress of the Centennial Exhibition at Philadelphia, measured one hundred corpuscles from each of fourteen men of different nationalities, using a one-twenty-fifth inch immersion objective and a cobweb micrometer eyepiece; the microscope thus arranged magnifying eighteen hundred diameters. He found the average diameter of the fourteen hundred corpuscles to be inch $\frac{1}{3224}$ or 7.879 microns. This is smaller than the measurement given in Dr. Treadwell's table, viz., 7.8938 microns.

While the general consensus of opinion among microscopists is that the blood of man can be distinguished with great certainty from the blood of such domestic animals as the pig, ox, horse, sheep, and goat, but few experts would venture any very positive diagnosis in criminal cases between the blood of man and that of the dog; though a *correct* diagnosis has been often given in experimental cases. Over twenty years ago Dr. Woodward published his results in the measurement of the corpuscles of dogs, giving averages which could not be distinguished from the measurements of human blood. Professor Wormley, Dr. Richardson, and Dr. Treadwell opposed his conclusions and sought opportunity (which was never given) to examine Dr. Woodward's specimens of dog's blood. At the famous Hayden trial before the superior court in New Haven, Conn., in 1879, Dr. Woodward explained his method of obtaining a large average of the blood corpuscles of the dog. He stated that he took blood from young dogs, spread on slides, and, looking over a slide till he found a collection of large corpuscles which have a tendency to collect together, he made his measurements from that collection. As a sample of his work, Dr. Woodward stated that on December 14, 1879, he measured 50 corpuscles from a pup four weeks old, a Newfoundland crossed with a setter, and found the average was 326-millionths of an inch, or 8.28 of a micron. December 12, 1879, he measured, selected in the same manner, 40 corpuscles from a Scotch terrier and got an average of 320-millionths of an inch, equal to 8.13 microns. From a Gordon setter full grown he measured 29 corpuscles and obtained an average of 300-millionths of an inch, equal to 7.62 microns. Dr. Woodward, when testifying under oath, said: "I desire to put myself on record as distinctly denying that those measurements of the dog's blood would represent what you would be likely habitually to get if, without picking out young dogs and without selecting a spot to measure appearing to have unusually large corpuscles, you were to measure dog's blood. You would then habitually get smaller figures than I have given here. The average of the corpuscles of dogs would habitually be smaller than I have given here, but I have purposely selected for fixed measurements young dogs, for I knew they had bigger corpuscles, and, in the second place, in taking an old dog, I purposely selected a place on the slide where, to my trained eye, I saw there was a group of big corpuscles. My reason for doing this is to show that if you pick up a half-dozen corpuscles by chance, you may chance on these big things. But I have nowhere stated that the average for the dog is as large as for man; on the contrary, I would like to read my express statement from my printed utterance, that the general average for the dog, for a great number of measurements, will be less than for a great number of men." Dr. Woodward appeared to contend that in examining blood stains you might chance to get a small speck of dried blood, from a dog, having principally these large corpuscles. This argument throws doubt upon any attempt to distinguish between the blood of man and that of the dog unless a large number of corpuscles have been measured. In Figs. 619 and 620 I give examples of the blood of man and the blood of a young female pug dog, both photographed by me on the same negative. They are magnified only 640 diameters in order to include a considerable number of corpuscles in the comparison. In this case no attempt was made to select a place where large corpuscles had collected. I should not attempt to distinguish with any degree of confidence in a criminal case between the blood of man and the blood of a dog.

As a difficulty in distinguishing the blood of different animals by microscopic measurement, Dr. Robert Ryburn (*Medico-Legal Journal*, September, 1892, p. 165) says, the trouble in our investigation of this subject lies in the fact that the blood corpuscles are living organisms that are not possessed of outlines delineated with mathematical accuracy. Replying to this objection we refer to Professor Wormley's statement ("Microchemistry of Poisons," p. 728): "In a series of ten spaces ruled on glass measured by three observers with different instruments the results did not differ more than $\frac{1}{200000}$ of an inch; and that two independent series of measurements, with high powers, of 20 designated blood corpuscles were absolutely identical for 16 corpuscles, and for the other 4 the greatest difference was only $\frac{1}{200000}$ of an inch." Still further, Professor Wormley reports the measurement of 7 human blood corpuscles, with powers from 1,150 to 3,500 diameters, by different microscopes, and by drawing with the camera lucida. The range of averages of the different measurements was $\frac{1}{3224}$ inch to $\frac{1}{3275}$ of an inch as measured by the camera lucida. The mean of the averages being $\frac{1}{3236}$ of an inch; the same 7 corpuscles measured by Dr. Richardson, using a cobweb micrometer, gave a final average of $\frac{1}{3266}$ of an inch, differing from the former average by something less than $\frac{1}{350000}$ of an inch. To further show the certainty of determining the exact limits of the border of the corpuscle and that different experts are likely to obtain the same results, I would mention that on a slide of human blood, irregularly spread, and dried so that the corpuscles on one half of the slide appeared larger than the other half, Dr. Treadwell measured, with high powers, 75 corpuscles on one side, showing the larger, and 75 on the side showing the smaller corpuscles. The average of the 150 corpuscles thus measured was $\frac{1}{3667}$ of an inch. The writer, using a power of 1,400 diameters and a cobweb micrometer, measured 50 corpuscles on one part of the same slide and 50 on the opposite part of the slide, and found the average of the 100 to be $\frac{1}{3665}$ of an inch, differing by only $\frac{1}{6719777}$ of an inch from the results obtained by Dr.

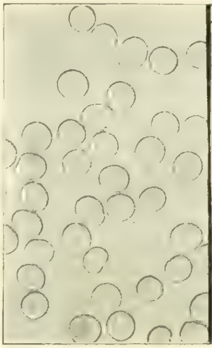

FIG. 619.—Human Blood. × 640.

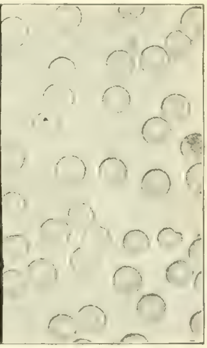

FIG. 620. Blood of Pug Dog. × 640.

Treadwell on the same slide. The above reported results remove, as I think, all objections attributed to the personal equation of the observer or the supposed indistinct or woolly appearance of the border of the blood corpuscle.

Prof. Marshall D. Ewell, M.D., LL.D., an excellent microscopist, in the *Medico-Legal Journal*, September, 1892, gives a report of very careful work in micrometry of 4,000 red blood corpuscles. He gives 9.06 microns as the average of 100 corpuscles from a boy thirty-six hours old, and 8.65 microns for another 100, or 8.85 microns as the average for 200 corpuscles; also the mean of 300 corpuscles from two puppies two days old as 8.22 microns, and that of 300 from a puppy eight weeks old as 8.43 microns. This report sustains the views stated above, that young animals have larger corpuscles. Professor Ewell shows by measurements of his own blood, taken on six different days, variations from 9.05 to 8.23 microns (the general average being 8.03 microns). This shows that for the same individual, while in health, the average of 100 or more corpuscles remains substantially constant.

Professor Ewell further says: "(1) There are such large discrepancies between the averages obtained from the measurement of the *fresh* blood corpuscles of animals of the same species, and between the measurements of the same objects by different observers, as to throw doubt upon the published results.

"In the use of the micrometric test no confidence can be placed in the results, unless the errors of the micrometer used, with reference to some authentic standard, are known.

"There is no advantage in using very high powers in such investigations." (By this statement he probably means that there is no advantage in using powers above a one-twelfth inch or a one-eighteenth inch objective as he has done. In this view of magnifying powers most microscopists at the present day are agreed; but when he claims that measuring ruled lines with a one-inch, three-fifth inch, and one-fifth inch objective is as good as with the higher powers, few experts would agree with him.)

"Many diseases alter the size of the red corpuscles; especially is this so in microcythæmia. Fasting diminishes both the size and number of the corpuscles. So also in the case of various drugs."

In view of the foregoing, according to the views of Professor Ewell, *it is impossible in the present state of science to say of a given specimen of blood, fresh or dry, more than that it is, or is not, the blood of a mammal.*

As the paper by Professor Ewell has been extensively quoted, and as Professor Ewell is now the most prominent opponent of medical experts on blood stains, the above conclusions will be further examined.

In regard to the micrometric test Professor Ewell's criticism does not apply to comparative measurements of blood of different animals where the expert, using always the same micrometer, bases his diagnosis on his own measurements alone. At present, however, it is easy for the expert to obtain micrometers made by skilful workmen and carefully rated by comparison with a reliable standard. Yet it is a remarkable fact that the measurements of human blood given by Gulliver, in 1875, $\frac{1}{3200}$; Wormley in 1885, $\frac{1}{3250}$; Schmidt, in 1848, $\frac{1}{3300}$; French Medico-Legal Society, in 1873, $\frac{1}{3257}$; Masson in 1885, $\frac{1}{3257}$; Hans Schmidt, in 1887, $\frac{1}{3412}$; Woodward, in 1875, $\frac{1}{3092}$; Formad, $\frac{1}{3200}$ — made at distant intervals and without comparison by a common standard—differ by only one-half of the difference between the blood of man and that of the pig. If Hans Schmidt did not measure the dark border of the blood corpuscle it would account for the small average which he obtained.

Another source of difference in measurement is in the mode of obtaining and preparing the blood for measurement. If a string is tied around the finger or the circulation is impeded in any other manner, and the blood is obtained by pricking with a needle, and is then spread upon a slide, the corpuscles, deprived of a portion of serum, will measure less than if obtained from a cut with a lancet where the circulation is not obstructed.

So also, if the blood is drawn from the prick of a needle in a warm and dry atmosphere, the corpuscles begin to contract before they can be spread upon a slip of glass.

None of these considerations enables us to reconcile all the discrepancies noticed by Professor Ewell in the writings of different authors; but the great fact is shown, by the unanimous consent of all microscopists, so far as we can ascertain, that less than 3,500 (most writers say less than 3,300) corpuscles of human blood are required to measure an inch, when placed side by side; while more than 4,000 corpuscles of the pig are required to measure an inch, and for the horse, ox, cat, sheep, and goat still more are required. Hence all authors agree that there is a remarkable difference between the average diameter of the human blood corpuscle and that of any domestic animal except the dog.

Taking the pig as the representative of domestic animals, because its corpuscles are larger than those of the ox, horse, cat, sheep, or goat, the following comparison between the blood of the pig and human blood is very significant:

To determine the extent of the possibility of mistaking the blood of the pig, ox, horse, sheep, or goat for human blood, we will examine the table of measurements made by J. B. Treadwell, M.D., using a one-twenty-fifth inch objective made by R. B. Tolles, and Jackson's eyepiece micrometer, made by Tolles, ruled by Professor Rogers, and a stage micrometer ruled, tested, and rated by Professor Rogers.

In this table the measurements of 3,000 corpuscles are given, 200 having been taken from each of fifteen different persons. The measurements are given maximum and minimum by tens, by twenties, by fifties, by one hundreds, and by two hundreds. Six hundred corpuscles from pigs were measured: 200 from a pig three weeks old, 200 from one of two months, and 200 from a pig three months old.

As the corpuscles of the pig have a larger average than those of the ox, horse, sheep, or goat, we make our comparison between the blood of man and the blood of these three young pigs:

			Microns.			Microns.
Man,	smallest	ten	7.658	Largest	ten	8.298
Pig,	"	"	5.418	"	"	6.520
Man,	"	twenty	7.662	"	twenty	8.191
Pig,	"	"	7.768	"	"	6.466
Man,	"	fifty	7.768	"	fifty	8.079
Pig,	"	"	5.880	"	"	6.246
Man,	"	hundred	7.852	"	hundred	8.046
Pig,	"	"	6.028	"	"	6.169

	Microns.
Smallest ten from man	7.658
Largest ten from the pig	6.520
Difference	1.138
This equals 0.000045 of an inch = $\frac{1}{22222}$ inch.	
Smallest twenty from man	7.662
Largest twenty from the pig	6.466
Difference	1.196
This equals 0.000047 of an inch = $\frac{1}{21278}$ inch.	
Smallest fifty from man	7.768
Largest fifty from the pig	6.246
Difference	1.522
This equals 0.000060 of an inch = $\frac{1}{16666}$ inch.	
Smallest hundred from man	7.852
Largest hundred from the pig	6.169
Difference	1.683
This equals 0.000066 of an inch = $\frac{1}{15151}$ inch.	

We thus see that where only 10 corpuscles are measured in man, taking the smallest average of 10 consecutively measured, this average for an adult man is one-sixth larger than the largest average of 10 consecutive corpuscles measured from a young pig only three weeks old; while the average of the smallest 100 from man, taken consecutively, is about one-fifth, $\frac{16}{78}$, larger than the largest 100 taken from the young pig.

Professor Ewell says: "Drying the blood corpuscles in a clot multiplies the difficulty of identification. It has never been proven that dried corpuscles can be restored to their normal proportions."

I would call attention again to the table on p. 84 of the present volume, which gives the measurements of 3,000 corpuscles of fresh human blood, including males and females, of all ages, from infants at birth to the man of seventy. The measurements are in microns.

Number of individuals.	Number of corpuscles.	Average	Max. Min.	By 10s.	By 20s.	By 50s.	By 100s.	By 200s
15 persons as stated.	3,000	7.938	4.233	7.658	7.662	7.768	7.852	7.913
			10.160	8.298	8.191	8.079	8.046	7.983
Blood stains, human	1,000	7.910	5.570	7.700	7.723			
			9.687	8.184	8.010			
3 young pigs	600	6.101	3.849	5.418	5.757	5.880	6.028	6.069
			8.391	6.520	6.466	6.246	6.169	6.144

Here we see that the average of 1,000 corpuscles restored and measured from stains of human blood is 7.910 microns, all probably being stains from the blood of adults; while the average from fifteen persons (three being infants) is 7.938 microns. The maximum, where infants are included, in fresh blood is a little more widely separated from the minimum than in the restored stains from adults. So also the range, when taken by tens or by twenties, is a little less for restored blood than for fresh blood, for the same reason. No closer similarity of results could have been expected had all the measurements been taken from fresh blood; one set including infants and the other being taken from adults alone. The fact that there is this difference, as given above, goes to show the great accuracy and perfect restoration of dried blood corpuscles to their normal dimensions.

As a further confirmation of the possibility of restoring dried blood stains to a condition in which their dimensions can be properly compared with fresh blood corpuscles, I copy by permission the following table from Professor Wormley's "Microchemistry of Poisons."

EXAMINATION OF OLD BLOOD STAINS.

Animal	Age of stain.	Remarks.	Average, inch.	Fresh blood, inch.
(1) Human	2 months old	Stain, unknown	1-3558	1-3250
(2) Human	2½ " "	Stain	1-3236	1-3250
(3) Human	3 " "	Stain	1-3334	1-3250
(4) Human	19 " "	Clot	1-3290	1-3250
(5) Elephant	13 " "	Clot	1-2849	1-2738
(6) Dog	4 " "	Trace of stain, unknown	1-3626	1-3561
(7) Rabbit	18 " "	Clot	1-3683	1-3653
(8) Ox	16 " "	Stain	1-4544	1-4219
(9) Ox	32 " "	Stain, unknown	1-4495	1-4219
(10) Ox	4½ years "	Clot	1-4535	1-4219
(11) Buffalo	18 months "	Clot	1-4312	1-4351
(12) Goat	17 " "	Stain	1-5897	1-6189
(13) Ibex	18 " "	Clot	1-6578	1-6445

"In the case of the human blood No. 1, two months old, the deposit was in the form of a thin stain on muslin, and its nature, other than that it was mammalian blood, was unknown at the time of examination. The corpuscles were readily found, and two series of thirty corpuscles were measured. In the human blood two and a half months old, fifty corpuscles ranging from $\frac{1}{3125}$ to $\frac{1}{3448}$ of an inch were measured.

"The blood stain of the dog, No. 6, was prepared by Dr. Frankenberg, and consisted of a single stain so minute as to be barely visible to the naked eye; its nature at the time of the examination was unknown. In this instance only fifteen corpuscles were measured. In the ox blood four and a half years old, the corpuscles were rather readily obtained, and two closely concordant series of measurements were made."

Another table, quoted by Clark Bell, Esq., in his article on "Blood Stains" in the *Medico-Legal Journal*, September, 1892, p. 157, is worthy of careful study in this connection. It shows results of examinations of blood dried on knives, glass, wood, cloth, paper, and stone, with measurements corresponding very closely with measurements of fresh blood.

I take great pleasure in acknowledging my obligations to Professor Ewell, from whose valuable articles on micrometric study of 4,000 red blood corpuscles, published in the *Medico-Legal Journal* for September, 1892, I have compiled the following table:

Source of blood.	Number of corpuscles.	Mean in microns.	Maximum.	Minimum.	By hundreds, maximum.	By hundreds, minimum.
Robust man	650	8.03	9.98	5.03	8.28	7.95
Boy thirty-six hours old	200	8.86	11.39	5.70	9.06	8.65
Adult man	100	7.85	9.32	6.73	....	....
Purpura hæmorrhagica	200	8.25	10.87	3.45	8.28	8.25
2 cases pseudo-leucocythæmia	400	8.04	11.04	6.56	8.55	8.42
Tuberculosis, anæmic	100	8.35	10.70	5.35	....	....
Plumbism	100	8.65	10.10	5.18	....	....
Gastritis	100	8.32	10.18	6.22	.	....
2 cases syphilis	200	8.11	9.32	3.97	8.11	8.11
Erysipelas	100	7.83	9.15	6.90	....	....
Pernicious anæmia	100	7.69	9.93	6.04	....	....
Menstrual blood	100	7.71	8.80	5.76	....	....
Whole number measured	2,350	8.14	11.39	3.45	9.06	7.95

In regard to the alterations of blood in disease, it is to be noted that no disease causing smaller average sizes of the blood corpuscles of the lower animals can have any tendency to cause such blood to be mistaken for human. If it was sought to ascertain whether a given stain, with corpuscles less than $\frac{1}{3500}$ or $\frac{1}{4000}$ of an inch, could have been obtained from a diseased human being, found by examination to have very small corpuscles, such a case would be judged by the facts discovered and possibly be indeterminable.

If we take $\frac{1}{3200}$ of an inch or 7.937 microns as the generally accepted average diameter of human blood corpuscles, and with it compare the average obtained by Professor Ewell from blood in disease, we find his largest average in plumbism, or lead poisoning, is 8.65 microns, or one-twelfth part larger than the normal average.

Now, if we take the young pig, which, excepting the dog, is the domestic animal having the largest corpuscles, and to the normal average, 6.101 microns, add one-twelfth its diameter, or 0.508 micron, we shall obtain for a possibly diseased pig an average diameter of 6.609 microns; which is smaller by 1.318 microns than that of the average human blood corpuscle. This difference when viewed in the microscope with a magnifying power of 2,500 diameters, the same power used in the photographs reproduced in Figs. 612 and 613, is equal to more than two and a half divisions of the scale in Fig. 613. With only 1,000 diameters the difference would be greater than one division of the same scale. Certainly no microscopist of ordinary skill would be in any danger of confounding blood of such a diseased pig with human blood recovered from a stain.

The only remaining possibility of mistaking stains from the blood of a pig, ox, horse, sheep, or goat for human blood, when fifty or one hundred corpuscles have been measured and found to average 7.9 microns, or even 7 microns, is to suppose it possible that the expert has *wickedly* and *purposely* measured only the largest corpuscles and has not done honest work. With a magnifying power of 1,000 diameters, a Jackson's micrometer measures with great certainty $\frac{1}{50000}$ of an inch. Professor Ewell's filar micrometer, as he states, is graduated to $\frac{1}{1000000}$ of an inch, and is certainly reliable to $\frac{1}{50000}$ of an inch, equal to one of the divisions on the above scale. Hence no expert can have any difficulty in recognizing with absolute certainty differences of 1.3 microns, equal $\frac{1}{20000}$ of an inch.

Professor Ewell says that "by selecting the corpuscles, it would be possible for a dishonest observer to make the average much larger or smaller than the above given [in his table] without the possibility of detection; a fact, the bearing of which upon the value of expert testimony upon this subject is so obvious as to need no comment." I have never claimed, and shall not now claim, that it is any more difficult for a witness to swear falsely in regard to blood stains than in regard to any other subject. But it would be quite possible on cross examination to ask the expert whether, in measuring the corpuscles obtained from a stain, he had measured all the well-defined corpuscles in the field of the microscope, or whether he had selected the large corpuscles and rejected others which were smaller.

In treating blood stains with solvents of fibrin, to liberate the corpuscles for measurement, it has been found in many cases that the corpuscles were smaller than in fresh blood unless maceration was long continued, old stains requiring several weeks before the corpuscles were in a condition to be measured. When a biconcave blood corpuscle is placed in water, the coloring matter (hæmoglobin) is dissolved out, the corpuscle swells up, thickens at the edges, becomes transparent and spherical. In this condition the diameter of the corpuscle becomes less than normal. It thus happens in examining blood stains that all corpuscles which have lost their color or have become spherical are by some experts rejected and not measured. Some corpuscles in fresh blood have much more coloring matter than others, and these corpuscles retain their color and form (as we think) much longer than paler corpuscles. We are not aware that any fluid used or likely to be used for softening blood stains will cause the corpuscles to become larger than normal. In this statement the most noted authors agree.

If the corpuscles obtained from a stain do not recover their normal dimensions it is almost absolutely certain that their average measurement will be less than normal and *never* greater than normal. Thus, in the language of Professor Wormley, we may confidently say: "*Thus, then, while the blood of man might on account of contractions in diameter of the blood corpuscles be confounded with that of some animal having smaller corpuscles, the reverse could never occur.*"

From this discussion I claim that it has been proved beyond any reasonable question:

1. That in favorable cases blood stains can be so treated that reliable measurements and credible diagnosis of their origin can be given, as shown in the tables given and in others which might be referred to.

2. That if error occurs on account of imperfect restoration of the form and diameter of the corpuscles obtained from a stain, proved (by (*a*) the guaiacum test; by (*b*) the spectroscope; by (*c*) the production of hæmin crystals) to be blood, the error, if any, will be to make human blood appear like that of one of the inferior animals, and never to mistake the blood of the ox, pig, horse, sheep, or goat for human blood.

3. In general, when a stain has been proved to be blood by the above tests, it may be decided certainly whether it is or is not mammalian blood. So, also, a stain from the blood of the ox, pig, horse, sheep, and goat may be distinguished from human blood, thus confirming the claim of an accused person in many cases that his clothes are *not* stained with human blood. This negative testimony is certainly quite as important in many cases as testimony inculpating a prisoner.

Lastly, the expert can say, when the average of a suitable number of corpuscles from a blood stain corresponds with the average of fresh human corpuscles, that the stain is surely not from the blood of the ox, pig, sheep, or goat.

Such testimony by a skilled microscopist is of untold importance in saving the lives of the innocent, and often in overthrowing the plea of those who are guilty. Such testimony is quite as reliable and important to the welfare of society as that of the chemist who testifies to the presence or absence of poison that might have some resemblance to the many recently discovered ptomaïns.

The testimony of the expert might take the following form, as recommended by C. H. Vibbert, "Précis de médecine légale":

"This stain is *not* composed of the blood of such an animal [ox, sheep, horse, pig, or goat] as the accused claims. It is like the blood of man, or some animal having corpuscles very nearly the same size as those of man, as the dog or rabbit."

Or the declaration may take the reverse form, thus: "This stain is *not* composed of human blood; it might be the blood of a horse, ox, pig, sheep, or goat, as claimed by the accused."

Such declarations are justified, then, and then only, when the examination has been conducted with great care and the measurements have been made with reliable instruments.

Moses C. White.

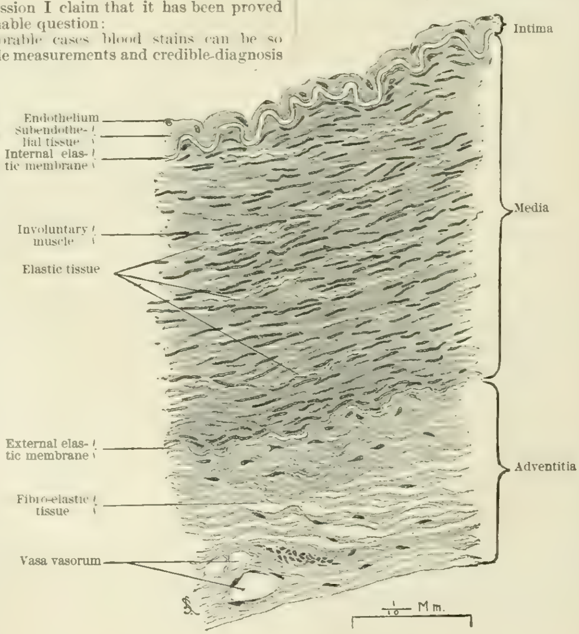

FIG. 621.—Section of Human Radial Artery.

BLOOD-VESSELS, HISTOLOGY OF.—THE ARTERIES.—An artery consists of three coats, which, named from their relative position, are the inner, the middle, and the outer. The structure and relative thickness of these coats vary in vessels of large, medium, and small calibre. A medium-sized artery, such as the radial, shown in the accompanying illustration (Fig. 621), has been taken as the type and first described in detail, the structural peculiarities of the larger and smaller vessels being subsequently noticed.

The *inner coat*, or *tunica intima*, is the thinnest coat of the artery and consists of three distinct structures: (*a*) an endothelial lining; (*b*) a layer of subendothelial connective tissue, and (*c*) an internal elastic membrane. The endothelial lining consists of a single layer of flat endothelial cells, each containing a centrally situated nucleus of round or oval form. When examined in a transverse section of the vessel, in which the cells are seen in profile, the endothelial plates are inconspicuous, the nucleus often being the only part of the cell readily made out. Examined from the surface, after staining with silver nitrate, the boundaries of the individual cells are clearly defined by the darkly tinted cement substance which unites the endothelial plates. In such preparations the lining cells appear spindle-shaped or lanceolate in form, their long axes corresponding with that of the blood-vessel. Careful examination of the outlines of the cell shows these to be serrated or sinuous, contrasting with the more regular lines of apposition in epithelial tissue. The lining cells of blood-vessels were first described by Kölliker and others as epithelium; later, His applied to them the name endothelium as more appropriate for elements derived from mesoderm and closely related to serous surfaces. In principle, endothelial cells are modified connective-tissue elements.

The *subendothelial layer* consists of bundles of white fibrous connective tissue interwoven with a delicate network of elastic fibres, and meagrely distributed branched connective-tissue corpuscles lying within the lymph spaces of the tissue.

The *internal elastic* membrane appears in arteries of medium size as a structureless, glistening, corrugated band that stands out as the most conspicuous structure of the intima. It constitutes the most external layer of the latter and forms a sharp line of demarcation between the narrow and faintly stained intima and the broad and more deeply tinted media. While apparently a homogeneous membrane in the smaller arteries, in vessels of large size the internal elastic membrane is represented by a number of delicate lamellæ of elastic tissue, which are pierced by apertures of varying size. The entire structure in these cases has been appropriately named the *fenestrated membrane of Henle,* in recognition of the anatomist who called attention to its peculiar arrangement. The majority of the elastic fibres forming this reticulated network run longitudinally, but are intermingled with some oblique fibres as well as a limited number of branched connective-tissue corpuscles.

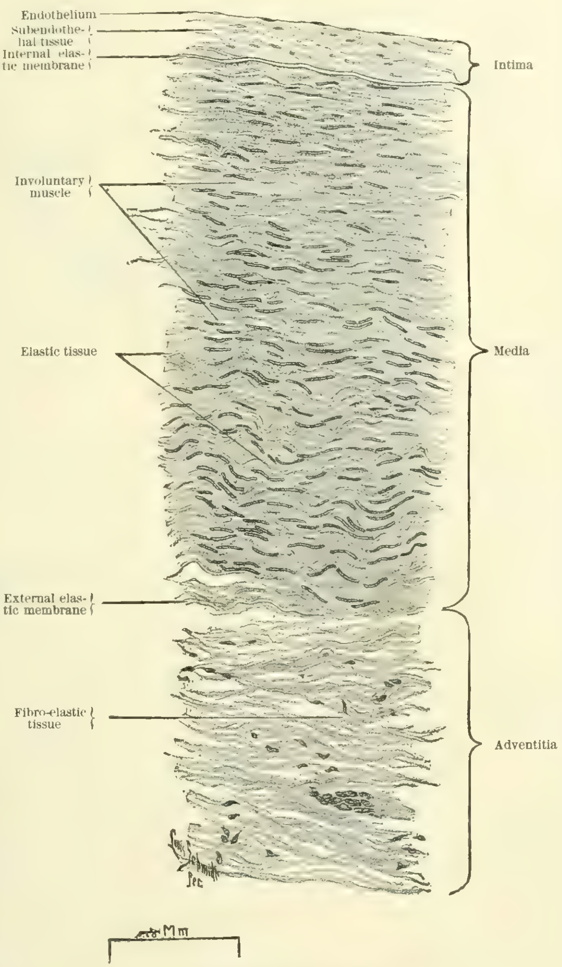

FIG. 622.—Section of Human Aorta.

The *middle coat,* or *tunica media,* is the thickest coat of the artery. It consists of circularly disposed lamellæ of involuntary muscle intermingled with connective tissue in which elastic fibres are conspicuous. The individual muscle cells are irregularly spindle-shaped, often with ragged outlines, and possess the characteristic rod-shaped nuclei. The muscle cells of the media are shorter and thicker than the slender and more elongated corresponding elements in other localities. The individual cells, held together by interstitial cement substance, are grouped into illy defined bundles, which are closely associated with small spiral bundles of white fibrous and elastic connective tissue, the whole forming the most compact coat of the artery. The elastic fibres are very numerous, and, in ordinary preparations being almost unstained, stand out in marked contrast among the more deeply stained masses of involuntary muscle.

The *external coat,* or *tunica adventitia,* is composed of closely felted bundles of white fibrous and elastic tissue arranged in fine wavy masses. Many of these bundles have a longitudinal direction, while others pursue an oblique course. Connective-tissue cells are present in considerable quantity. While looser in texture and apparently of less strength, the adventitia is nevertheless more resistant than either of the other coats, and is the tunic upon which the integrity of a ligature chiefly depends. The walls of the arteries are nourished by a special system of minute vessels, the *vasa vasorum*, which enter the adventitia and penetrate the media. The vasa vasorum do not spring from the vessels which they supply, but are usually derived from neighboring arteries, the blood flowing through the larger vessels having as a rule no direct relation with that within the vasa vasorum.

The differences distinguishing the coats of a large artery from those of a vessel of medium size consist, in general, of an increase in the thickness of the various tunics, as shown in the accompanying Fig. 622.

The immediate lining of even the largest arteries consists of a single layer of endothelial cells; the subendothelial tissue, however, is greatly thickened not only relatively but also absolutely. The subendothelial bundles of white fibrous tissue are coarser, and the elastic tissue is present in greater amount and constitutes the fenestrated elastic membrane of Henle. The media likewise is thicker, the increase, however, being due not so much to the greater amount of involuntary muscle as to the addition of fibro-elastic tissue, which here bears a much greater proportion to the muscular tissue. This increase of fibro-elastic tissue is responsible for the diminution of elasticity and the increased stiffness which characterize the walls of the larger arteries. The elastic tissue of the media in the latter vessels is often condensed to form an *external elastic membrane*, which defines the boundary between the media and the adventitia. The adventitia is also thicker, but the increase in this tunic is proportionately less than that affecting the intima and media. The adventitia of small arteries, in relation to the other two coats, is thicker than that of the large arteries.

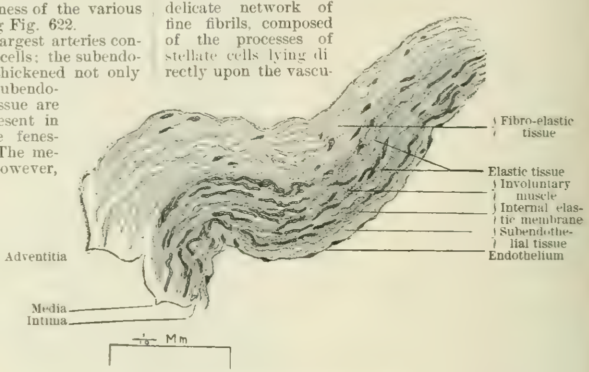

FIG. 624.—Section of Human Radial Vein.

The small arteries and arterioles, on the other hand, differ from the medium-sized vessels by a reduction in the thickness of their coats. The subendothelial tissue almost entirely disappears, while the involuntary muscle of the media is reduced to an attenuated layer of muscle cells, with little or no admixture of fibro-elastic connective tissue. The adventitia consists of a few longitudinal bundles of fibrous tissue, with often an absence of elastic fibres.

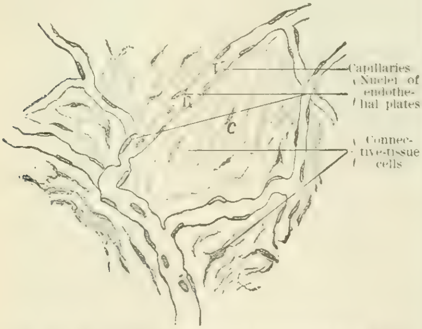

FIG. 623.—Capillary Blood-Vessels from Mesentery of Dog. × 240.

The capillaries are microscopic vessels establishing communication between the arteries and the veins. In the tips of the fingers, the tips of the toes, the tip of the nose, the splenic pulp, and the erectile or cavernous tissue of the genital organs the arteries communicate directly with the veins. A capillary consists of a single layer of nucleated endothelial cells united by a small amount of intervening cement substance. By reason of the character of their thin walls, they are virtually protoplasmic tubes admirably adapted to facilitate the distribution of nutritive fluids to the tissues or, as in the pulmonary alveoli, to the interchange of gases. As the capillaries become larger a delicate tunica adventitia is superadded, which is formed of a delicate network of fine fibrils, composed of the processes of stellate cells lying directly upon the vascular walls. Each of these stellate cells consists of a large elongated nucleus, invested by an extremely delicate layer of protoplasm. The protoplasm of which the cells are composed is always more abundantly and distinctly granular toward the centre and around the nucleus, whilst near the margin it is quite clear, and thins off to a delicate border. The capillaries by their union constitute the capillary plexuses, *retia capillaria*, which are more or less constant in the different organs. The forms presented in these plexuses depend to some extent upon the disposition of the elementary parts, and are also in some degree dependent upon the energy of the function. There are in many organs certain tissues into which vessels never penetrate,—as the transversely striped muscular fibres, the nerve fibres, cells of all kinds, gland acini,—and which, therefore, according to their form, trace out definite courses for the capillaries, so that they sometimes present elongated meshes, sometimes rounded, narrower, or wider reticulations.

The mode in which the capillaries pass into the larger vessels is interesting. On the arterial side it is found that the capillaries, as they become wider, present more closely placed nuclei, and are then invested externally with a structureless tunica adventitia and solitary muscle cells, the whole structure exhibiting the aspect of arterioles. On the venous side the transitionary vessels are less characteristic for a greater length. The first thing that is superadded, on this side, to the capillary wall is an external, homogeneous nucleated layer, which may be regarded as a sort of connective tissue—the tunica adventitia,—forming a distinctly laminated structure, the veinlet. Besides the finest capillaries, which, however, always admit the passage of very flexible blood corpuscles, some observers have admitted the existence of still finer vessels, the so-called *vasa serosa*, which no longer allow of the passage of blood, but only of its plasma. Hyrtl thinks that it is necessary to admit of the existence of vessels of this kind in the cornea.

Among the *structural peculiarities* of certain arteries may be mentioned the slight development, or even complete absence, of the subendothelial connective tissue in the cœliac, the external iliac, the mesenteric, the renal, and the uterine arteries of young individuals. The aorta possesses a marked development of the subendothelial connective tissue, as well as the presence of longitudinal muscle cells within the intima. Longitudinally disposed muscle is present in the media of the subclavian artery and in the adventitia of the iliac, the superior mesenteric, the splenic, the renal, and the dorsalis penis, as well as in the umbilical arteries of the fœtus. Some arteries, notably the vessels within the cranial cavity and the vertebral canal, possess coats which are very thin in proportion to their calibre. In these vessels, however, it is the media and the adventitia that suffer reduction, the intima remaining almost unaffected.

A typical vein, as shown in the accompanying drawing, (Fig. 624) has thinner walls and a larger lumen than the corresponding artery; to this rule, however, the pulmonary veins are exceptions, since they are of the same capacity as, or of less capacity than, the pulmonary arteries. The constitution of the coats of a vein is less constant than it is in an artery, variations in the arrangement, proportion, and amount of the component tissues being very frequently encountered.

The *inner coat*, or *tunica intima*, consists of (*a*) endothelial cells, (*b*) subendothelial connective tissue, and (*c*) elastic fibres. The endothelium is composed of a single layer of cells held together by interstitial cement substance. The cells are shorter and wider than the corresponding lanceolated elements of the artery. The subendothelial connective tissue is very scanty in the majority of veins and rudimentary or even entirely absent in the smaller ones. The elastic tissue often represented by a few longitudinal bundles is less developed and does not form a fenestrated membrane.

The *middle coat*, or *tunica media*, is much thinner and looser than in the artery, chiefly on account of the admixture of connective tissue associated with the circularly disposed involuntary muscle cells. The elastic fibres, so conspicuous in the media of the artery, are very few in the vein.

The external coat, or tunica adventitia, is the thickest coat of the vein, reaching often twice or even three times the breadth of the media. It consists of wavy bundles of white fibrous tissue, usually following a circular direction, among which a few longitudinal fibres may be found; the greater number of the latter fibres are of the elastic variety. Connective-tissue cells are present in considerable number. The walls of the vein are nourished by vasa vasorum similar to those supplying the arteries.

Many veins, especially those of the lower extremities, are provided with valves; these are crescentic folds of the intima, which are brought into apposition by the dilatation of the pockets formed between the attached portion of the valve and the wall of the vessel. The valve consists of an extension and thickening of the fibro-elastic tissue of the intima, covered on each side by endothelial cells. The free edge of the valve is thicker than the attached border.

The variations in the structure of veins depend largely upon modifications of the muscular tissue. The involuntary muscle is best developed in the media of veins of the inferior extremities; in the veins of the gravid uterus involuntary muscle occurs in the adventitia as well as in the intima. Additional longitudinally disposed bundles of muscle are present in the inner part of the media in the mesenteric, the iliac, the femoral, and the umbilical veins. Involuntary muscle is sometimes encountered in the adventitia, in the abdominal cava, the axillary, the hepatic, the external iliac, the superior mesenteric, the renal, the splenic, the spermatic, and the azygos major veins. The presence of striated muscle in the pulmonary veins and cardiac ends of the venæ cavæ is to be regarded as an extension of the striped muscular tissue of the auricular wall.

Robert Formad.

BLOOD-VESSELS, PATHOLOGICAL ANATOMY OF.—The Capillaries.—The capillaries are less independent structures than the arteries and veins, and the pathological changes in the capillary wall are generally intimately connected with lesions in the surrounding tissues. The important rôle played by the capillaries in the different forms of inflammation is discussed in the article on *Inflammation*.

All tissue proliferation, whether inflammatory or noninflammatory, is almost without exception associated with the new formation of capillary vessels by processes of budding of pre-existing capillary endothelium, and these changes are described in the article on *Regeneration*.

Capillary new formation lies at the bottom of tumors composed of capillaries, the capillary angiomata and teliangiectasias of congenital or acquired origin; they form mostly flat tumors of the skin and subcutaneous tissue, of a bright red color and a soft feel; the capillaries in them have thick cellular walls, and there is abundant evidence that new capillaries have been formed. Similar changes occur in capillaries in other tumors (see *Tumors*).

Long-continued congestion will result in dilatation of the capillaries, capillary ectasis or capillary aneurism; this is shown well in passive congestion of the lungs.

Hyaline degeneration of the capillary walls is frequently observed in the brain, especially in paralytic dementia, but also in the kidney, the conjunctiva, the lymph glands, and in various tumors. Hyaline degeneration of the glomeruli is an important alteration in chronic nephritis, especially the interstitial form. Hyaline degeneration is a rather vague term and the exact origin of hyaline material is not understood. In certain tumors mucoid degeneration of the capillary walls sometimes takes place.

Mallory in his study of colloid or hyaline changes in the brain shows that the material is always deposited in the vessels; in the larger vessels the middle coat is earliest and most affected. The hyaline material has a marked tendency to calcification, and in some cases the capillary network of the central cortex, the dentate nucleus, and the granular layer of the cerebellum undergoes hyaline change with calcification; this causes atrophy of the included nervous tissue and leads to the formation of sand-like deposits and of stone-like concretions.

Fatty changes in the capillary epithelium* occur frequently, especially in the nervous system and in the various toxic and infectious states. The lesions in the capillaries that may underlie the tendency to spontaneous hemorrhage in the hereditary and acquired hemorrhagic diathesis have not yet been cleared up; in these conditions it is difficult to determine whether the hemorrhages result from diapedesis or from rhexis. The relations of the capillaries to thrombosis and embolism are described in the articles dealing with those subjects.

Calcareous infiltration of the capillary walls occurs in the brain of old people; generally calcification is preceded by hyaline degeneration. Calcification of the capillaries also takes place in certain tumors, especially psammoma.

Amyloid degeneration is an important change in the capillary walls, observed always in the capillaries of the spleen, kidneys, liver, etc., in general amyloidosis. The amyloid material appears first in the delicate capillary sheath outside of the epithelium, which is soon crowded to one side and the lumen closed.

The Arteries and Veins

Abnormities.—Congenital abnormities of blood-vessels may concern width, thickness of wall, origin, and course. Deviations from the normal in these respects on the part of the smaller and medium-sized vessels are considered to best advantage in connection with the normal anatomy of blood-vessels.

The congenital defects and anomalies of the *pulmonary artery* and *aorta* are closely associated with defects and anomalies of the heart. Among the important irregularities of the primary vessels is transposition of the aorta and the pulmonary artery. This may occur in hearts that are not otherwise defective or in association with other developmental anomalies of the heart. Transposition of the venæ cavæ and the pulmonary vein is also described. In nearly all cases of this kind the foramen ovale is open to a greater or less extent and generally the ductus arteriosus is pervious. In some cases the only communication between the two circulatory systems was through the widely open foramen ovale. Death occurs in early infancy.

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* The term "epithelium" is used in place of endothelium in this article.—L. H.

The septum between the aorta and pulmonary artery may be defective. In an instance of this kind that I examined there was an oval defect about 1.5 cm. in its greatest diameter between the pulmonary artery and the aorta, so that the beginning of the aorta and pulmonary artery had a common trunk from which emerged, in the usual places, the right and left pulmonary arteries and the branches of the arch of the aorta. The ductus arteriosus was patent and large, the aorta distal to the duct wider than that proximal to the duct. The foramen ovale was widely open. The large veins and the heart were normal.

Instances of aortas with double arches are described by Hommel, Curnow, Malacarne, Zagorski, Welch, and Lee Shaw. According to Lee Shaw, Hommel, in 1737, was the first to record this anomaly. In his case the two divisions united after encircling the trachea, and passed downward on the left side of the vertebral column. Malacarne's report, as described by Meckel and Quain, differs from all the others. Five valves guarded the aortic opening of the left ventricle and the arterial trunk immediately divided into two branches, which before uniting embraced the pulmonary artery, trachea, and œsophagus; from each division was given off in succession a subclavian, an external, and an internal carotid artery. In Welch's case, the posterior branch passed between the trachea and œsophagus, and from each division arose a common carotid and a subclavian artery. On the posterior branch was found an aneurism from which the right common carotid took origin. Lee Shaw's specimen differs from all of those described except Malacarne's, in that the two divisions unite behind the œsophagus. It differs from all in that the right branch is the larger, the junction of the two branches is on the right side, and the descending aorta passes downward on the right side, to the upper border of the eighth dorsal vertebra. This arrangement not only resembles the vascular arrangement in the reptile, but also more closely follows the distribution in the bird than it does that in the mammal.

Such anomalies of the aorta are probably due to the persistence and enlargement of fetal vessels which normally become obliterated. From the embryonal aortic bulb two vessels arch backward, one on either side of the foregut, forming the first pair of vascular arches, and descend along the sides of the notochord as the primitive aortæ. As the heart gradually moves away from the head, four more pairs of vessels develop, which connect the bulb with the descending trunks; making in all five pairs of arches, one for each branchial plate. Zimmerman describes an additional pair between the fourth and fifth.

"The bulb, primarily a single cavity from which, through two common trunks, one on each side, blood is sent to all the arches, is divided by a septum parallel to its long axis into two compartments: one becoming the pulmonary artery, situated anteriorly, and continuous with the fifth pair of arches, the other forming the systemic aorta, placed posteriorly, and communicating with the fourth pair, through which all the arches above receive their blood supply. Notwithstanding this separation near the heart, both pairs of arches, *i.e.*, the fourth and fifth, ultimately empty into the descending aorta which has been formed by the coalescence of the primitive aortæ.

"This symmetrical arrangement of the vascular system is soon destroyed by the obliteration of certain vessels. Even before the last arch is perfectly formed the connections between the first pair and the descending aortæ may be destroyed. However, the fourth and fifth arches, lying nearest the heart and soon exceeding the others in size, are the chief factors in this transformation. The vascular arches on the left side continue to increase in size and in greater part become permanent, while those on the right gradually become obliterated, except where they furnish the supply to permanent arteries.

"On the left side the fourth arch becomes the arch of the aorta and, in the fœtus, is constructed between the origin of the left subclavian and the junction of the ductus arteriosus, forming the isthmus, which soon after the closure of the duct attains the diameter of the adjacent trunk. The fifth, on this side, forms a part of the left pulmonary artery and the ductus arteriosus, which is occluded soon after birth but remains as a round cord. On the right side the fourth arch is permanent for a short distance as the innominate and right subclavian arteries, as far as the origin of the vertebral, beyond which it diminishes in size and finally disappears. Only a small portion of the fifth persists on this side as the root of the right pulmonary artery; the distal portion becomes obliterated."

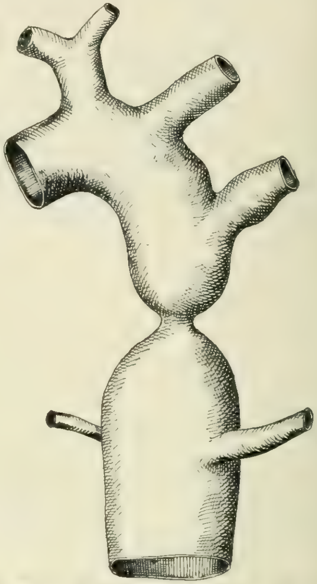

Fig. 625.—Stenosis of Aorta at Ductus Arteriosus. (Modified from Cruveilhier.)

In Lee Shaw's case, the fourth arch on the right side not only remained patulous, but exceeded the left in size. The fourth arch of the left side retained some of its fetal characteristics, because it was doubtless unnecessary for the isthmus to enlarge after occlusion of the ductus arteriosus, as the blood current could easily pass through the right arch.

Premature obliteration of the ductus arteriosus has been described as causing an abnormal smallness of the pulmonary artery. The pulmonary artery may divide at a point lower than usual, or arise by two distinct roots, instead of continuing into the aorta as the ductus arteriosus; it may form the left subclavian artery. Supplementary or vicarious branches distributed to the lungs may arise from the aorta as far down as the cœliac axis.

In narrowing or obliteration of the aorta after having given off the vessels to the head and upper extremities, the inferior parts of the body are supplied with blood from the pulmonary artery through the ductus arteriosus;

the descending aorta is said to be given off from the pulmonary artery. Now if the degree of constriction of the aorta be but slight at the time of birth, the ductus arteriosus may become closed. Later in life great narrowing and even complete obliteration of the aorta may take place (Fig. 625).

The theory usually offered in explanation of the pathogenesis of this condition was first broached by Skoda in 1855. The narrowing is made dependent upon the presence in the walls of the aorta of embryonal connective tissue connected with the ductus arteriosus; the postnatal involutional changes then lead to varying degrees of stenosis of the lumen of the aorta. Aberrant vestiges of duct tissue may occur in the aortic walls. Thrombosis of the aorta beginning in the ductus arteriosus may end in complete aortic obliteration (Rauchfuss).

Of 113 cases of narrowing and closure of the aorta at or near the opening of the ductus arteriosus studied by Wadstein, atresia was present in 20. In 16.4 per cent. the maximum narrowing was above the duct, in 33.8 per cent. on a level with the duct, and in 44.8 per cent. below it. The narrowing is sometimes double. In about a third of the cases the aorta was sclerotic, and generally more so on the proximal side of the narrowing. The most important secondary changes are hypertrophy of the left ventricle and the formation of collateral circulation, the blood reaching the lower portion of the body through the intercostals and the abdominal aorta, through the superficial epigastric and long thoracic arteries and the deep epigastric, and through the anastomoses of the intercostals with the ilio-lumbar and circumflex iliac arteries.

The ductus arteriosus is as a rule completely obliterated within from one to two weeks post partum. The obliteration is accomplished by contraction and endarterial proliferation. The resulting scar in the wall of the aorta often becomes calcified. Incomplete involution of the ductus arteriosus may become the occasion for thrombosis; the thrombus may project into the aorta and into the pulmonary artery and give rise to embolism (Klob).

Transposition of the *large veins* occurs in connection with cardiac abnormities. There may be two ascending or two descending venæ cavæ, in the first case due to failure of union of the canals of Cuvier; less than or more than four pulmonary veins, which may be inserted into the superior vena cava, into the left innominate vein, or into the ventricles. Either of the venæ cavæ may be absent. An apparent reduplication of the inferior vena cava results from the union of the hepatic veins in one stem, which may empty into the vena cava above or below the diaphragm, or directly into the right auricle. The union of the iliac veins may take place higher than usual, the right and the left iliac vein continuing upward on each side of the aorta, sometimes as far up as the liver.

Coronary Arteries.—Abnormities of the coronary arteries have been described by Hepburn, Turner, Brooks, and others. The most frequent deviation from the normal is an increase in number and irregularities in branching. Brooks describes the origin of a coronary artery in the right anterior sinus of Valsalva of the pulmonary artery; this abnormal coronary anastomosed with the right coronary and acted as a vein owing to the greater pressure in the aorta. In another, more complicated case, Brooks found an artery originating in the beginning of the pulmonary artery, anastomosing with the aortic coronaries and the left subclavian artery; it entered into intimate relations with a cirsoid mass at the base of the pulmonary artery. This vessel also acted as a vein, emptying its blood into the pulmonary artery.

Aplasia or hypoplasia of an organ or part of the body is associated with absent or diminished development of the corresponding blood-vessels. Abnormal origin and course of arteries and veins are of greater surgical than clinical interest, because it is exceedingly rare to observe that such abnormities cause symptoms. The origin of the right subclavian artery to the left of the left subclavian artery and its coursing in front of or behind the œsophagus as it passes over to the right side may cause difficulties in swallowing, according to Eppinger. Differences in the size of the radial arteries and in the relative depths of their situation frequently give rise to apparent differences in the pulse on the strength of which the existence of aortic aneurism may be erroneously diagnosticated.

Vascular Hypoplasia.—Congenital smallness of the entire cardio-vascular system is an interesting condition. Morgagni, Meckel, Rokitansky, and Virchow have drawn attention to this arrest of development, especially in chlorosis. The walls of the aorta are thin, the intima is the seat of wavy lines, and the lumen scarcely admits the little finger at a period when the aorta usually is twice or more as wide. The condition is frequently associated with arrested development of the reproductive organs and of the sexual characteristics of the body. Apparently the anomaly is probably more frequent in the female than in the male sex. It has been thought that a hypoplasia of the entire mesoblast is present, including the blood-forming organs; hence the peculiar anæmia which is thus explained according to Virchow's theory. The explanation is no longer regarded as satisfactory. "That a disorder so common and for the most part so curable should depend upon a malformation so grave and so incurable as this aortic and general vascular hypoplasia is on the face of it highly improbable" (Clifford Allbutt).

The developmental defects in the vessels in hæmophilia are considered under the latter heading.

Retrogressive Changes in Blood-Vessels.—Retrogressive changes of blood-vessels pure and simple are not of so much importance as when associated with other processes in the condition known as angiosclerosis.

Atrophy.—In chronic anæmia and marasmus simple atrophy takes place in the walls of the blood-vessels, especially in the muscular coat. Atrophy of individual organs is followed by or associated with atrophy of the corresponding vessels. When an extremity is removed the arteries and the veins that nourished the part decrease in size by an atrophy that may be called adaptive; the vessels become less and less until they carry no more blood than necessary for the nutrition of the remaining tissues (Fig. 626). In the beginning this adaptation is favored by contraction of the arteries and a little later by the development of new connective tissue in the intima, so that the lumen of the arteries is reduced in size.

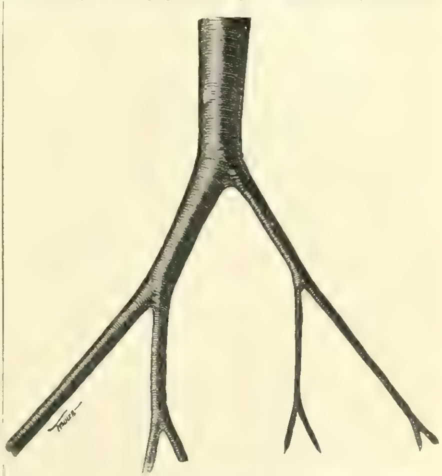

Fig. 626.—Atrophy of Left Iliac Artery After Thigh Amputation. (Two-fifths natural size.)

Fatty Changes.—Changes in the composition of the blood or disturbances of circulation may induce fatty changes in the walls of otherwise healthy blood-vessels, especially in the epithelial cells and the muscle cells of the arteries. Fatty changes are of common occurrence in arteriosclerosis. A vessel the seat of fatty change presents upon its surface opaque white or yellowish-white patches and irregular lines, running longitudinally or forming a network, sometimes striated, sometimes of a uniform color. The surface is no longer smooth but velvety. These appearances are due to fatty granules and drops of fat in and between the epithelial cells. The change occurs also in the endothelial cells of capillaries. Cells may accumulate around and in areas of fatty change, taking up the oily detritus, and proliferation of cells also occurs.

Disintegration of the degenerated areas results in small defects ("fatty ulcers") which may become the starting point of thrombosis or traumatic and dissecting aneurisms; on supervention of trauma or severe strain the deeper layers of the intima are ruptured and the blood current makes its way between the layers of the arterial wall. According to Paget fatty degeneration of the media is responsible for many instances of cerebral apoplexy. Fatty changes in the media are common in various intoxications. Fatty changes are frequently followed by calcareous infiltration, the arterial wall becoming rigid and inelastic.

Fatty changes occur most commonly in the aorta and the pulmonary artery, and then in the arterioles and capillaries, especially of the brain.

In veins fatty changes in the intima form white spots, but the veins are not as frequently affected as the arteries.

Amyloid Degeneration.—The vascular system is especially prone to amyloid change, which takes its beginning in the media of the arterioles of parenchymatous organs. It also develops in the intima of the larger arteries in extensive widespread amyloid change, appearing as fine striæ and points, which are difficult to recognize with the naked eye unless first subjected to the action of Lugol's solution (see *Amyloid Degeneration*).

Hyaline Degeneration.—Hyaline degeneration of the smallest arteries and veins and of capillaries is frequently observed in the spleen, the lymph glands, the renal glomeruli, and elsewhere. The epithelium, at first intact, is finally destroyed and the lumen narrowed and occluded. In the larger vessels hyaline degeneration appears first in the intima, and it forms an early step in the complicated degeneration of arteriosclerosis. Hyaline material tends to become calcified. A good example of a hyaline degeneration of the muscular coat is seen in the pial arteries in tuberculous leptomeningitis.

Calcareous Infiltration.—Calcareous particles in glistening granules and as compact masses are frequently deposited in hyaline and fatty areas; it probably does not occur as an isolated primary process, and is most frequent and most extensive in senile arteriosclerosis. Gazert found that in a normal aorta the amount of earthy material is .43 per cent.; in a sclerotic and calcified aorta the calcareous material equalled 8.79 per cent. of the dry residue.

Metastatic calcification as a result of resorption in bone is said to involve especially the abdominal vessels, large calcareous plates forming which are separable from the surrounding tissues.

In some instances *true bone* has formed in the walls of arteries the seat of petrification. Ossification means preliminary vascularization, absorption of pre-existing calcareous material, and the formation of genuine bone. Von Schrötter and Falk describe with illustrations extensive ossification of arteries in senile gangrene; Cohn found true bone in the aortic valves and in the media of peripheral vessels.

Desquamation of the Epithelium.—In microscopic sections the epithelium of the vessels, both arteries and veins, is found occasionally to have separated from the intima, the peculiar epithelial cells lying curled up in the lumen. This condition is not constant, and the peculiar circumstances under which it occurs have not been established. The loosened epithelial cells have been mistaken for sarcomatous emboli.

Hypertrophy and Hyperplasia.—Hypertrophy and hyperplasia of arteries are observed in connection with various forms of tissue overgrowth, *e.g.*, the uterus in pregnancy, large tumors, and the adaptive hypertrophy of one kidney in case of extensive disease or absence of the fellow kidney. Obstruction to the blood current and increased arterial tension, as in cases of hypertrophy of the heart and of chronic nephritis, produce more or less hypertrophy of the muscular coat of the arteries. The power of the arteries and veins to adapt themselves to new conditions is best shown by the changes that take place in the development of collateral circulation. Indeed, this is one of the richest fields for the study of pathological adaptation. Vessels and vascular systems adjust themselves with wonderful precision to changes in pressure, in velocity, and in quantity of circulating blood. Readjustment is accomplished by virtue of the vaso-motor nervous mechanism and the physical properties of the arterial walls, aided under special conditions by structural changes. The physiological prototype of collateral circulation is seen in the changes that occur in the fetal circulation after birth. The ease with which the important rearrangements to the conditions of extra-uterine life are accomplished indicates that the mechanisms for adaptive changes on the part of the circulatory system are good; as in almost all pathological adaptations, the mechanisms are in better working order in the young than in the adult and the old.

The extent of the changes incidental to the development of collateral circulation will depend naturally upon the location of the obstruction and upon the size and the number of the collateral branches. Formerly it was taught that the increased pressure above the obstruction was the cause of the development of collateral circulation; increased pressure is now regarded as a factor of little consequence. Nothnagel has shown that there is really no rise of pressure in the vessels above the obstruction or ligature unless they stand in communication with branches below the obstruction. As advanced by von Recklinghausen, the increase in the extent of the capillary bed of the collateral branches, through which the blood flows into the capillaries of the obstructed vessel, results in increased rapidity of the current; and Thoma has demonstrated that increased rapidity of the current is followed by a widening of the lumen of the vessels, increased thickness of the wall, and growth in length. In this way the need of the tissues for blood is satisfied. The structural changes that take place in the walls of the collaterals may be regarded as the expression of a work-hypertrophy. And conversely, the gradual thickening of the intima of the occluded vessel as far back as the nearest collaterals is to be regarded as the result of diminished need of work.

In obstruction to the portal circulation by cirrhosis of the liver the dilatation and hypertrophy of the veins through which collateral circulation is gradually established may become marked. In exceptional cases the œsophageal veins become enlarged to many times their normal size and afford so complete escape for the portal blood that the congestions and the ascites of cirrhosis fail to appear and the clinical picture of the disease is masked.

Inflammation (Angeitis, Vasculitis).—Inflammation may affect principally the adventitia, the media, or the intima (periarteritis and periphlebitis, mesarteritis and mesophlebitis, endarteritis and endophlebitis). On account of the structure of the venous wall, these distinctions are not as marked in veins as in arteries. Angeitis may assume various types, such as productive, suppurative, tuberculous, and syphilitic. Angeitis may result from the extension of inflammatory processes in the neighborhood (consecutive angeitis); it may be caused by wounds of arteries or veins and by other forms of trauma, such as tearing and crushing (traumatic arteritis and phlebitis); it develops as a result of infections (pyogenic, syphilitic, and tuberculous) and of intoxications; in angeiosclerosis arteritis and phlebitis are observed as consecutive processes, secondary to nutritive and mechanical disturbances in the vessel wall. Arteritis and phlebitis sustain a double relation to thrombosis inasmuch as thrombosis in an artery or a vein induces inflammation (thrombo-arteritis, thrombo-phlebitis) while angeiitis not uncommonly leads to thrombosis. The causes of infectious or toxic angeiitis may reach the part of the vascular wall first involved through either the vasa vasorum, the lymph stream, or the main blood stream within the lumen of the vessel, or they may come directly from without.

It was the custom of pathologists in the early part of this century to look upon imbibition and reddening of the tunica intima as evidences of acute inflammation; in 1847 Virchow proved the incorrectness of this view.

Because the same agent may produce more than one form of arteritis and phlebitis, and because the same form of angeiitis may result from more than one cause, it becomes rather difficult to make at once a comprehensive yet simple classification of arteritis and phlebitis. When we omit from consideration periarteritis nodosa and the specifically tuberculous and syphilitic varieties, then the remaining forms belong to one of two large groups, the suppurative and destructive or the productive, the first characterized by disintegration and the formation of pus, the second by the production of new tissue.

Suppurative Angeiitis; Suppurative Thrombo-Arteritis.—The form of disease of the arterial wall induced by thrombosis or by the lodgment of emboli is determined by the nature of the thrombus or embolus. In the case that pyogenic bacteria are present in their interior, purulent inflammation is set up in the walls of the artery, resulting in a more or less extensive and destructive panarteritis and periarteritis, the final outcome being an abscess. This is what occurs in the development of metastatic embolic abscesses in the lungs. At other times the destructive action of the bacteria in infected emboli may be more limited in its extent, thereby producing a local weakening of the arterial wall, at which point aneurismal bulging occurs and there results a so-called embolic or mycotic aneurism (Goodhart, Eppinger). Mycotic embolism, the result of embolic suppurative arteritis, is observed most frequently in the cerebral arteries. Purulent thrombo-arteritis, with or without mycotic aneurism, is liable to result in hemorrhage from the weakening and destruction of the vessel wall.

Suppurative Thrombo-Phlebitis.—This may result from the extension of a suppurative process about a vein to the adventitia, media, and intima, which is more frequently the case than thrombosis upon the basis of a primary mycotic endophlebitis. In either case the resulting thrombosis undergoes purulent or purulent and putrid softening under the influence of the microbes that gain entrance into it from the walls of the vein. Beginning with John Hunter, in 1793, who described inflammation of the inner walls of veins after blood-letting and in the uterine and femoral veins of women in the puerperal period, it gradually became established clearly that pyæmia commonly depends upon suppurative thrombophlebitis, the circulating blood being the medium of transference of infected particles from the thrombus to various parts of the body, the emboli on lodgment producing metastatic abscesses. Among veins that are liable to suppurative thrombo-phlebitis may be mentioned the umbilical veins in the new-born, infection taking place at the navel; the lateral and other sinuses of the dura mater in suppurative mastoiditis and middle-ear disease; the mesenteric veins in appendicitis and ulcerative processes in the intestines, the process giving rise by extension or embolism to suppurative pylephlebitis and abscesses of the liver; the subcutaneous veins in the vicinity of the foci of infection, etc. Suppuration originating in a diverticulum of the œsophagus has extended to the superior vena cava and given rise to suppurative thrombo-phlebitis in this vein.

Mycotic and Toxic Endangeiitis.—Acute verrucose and ulcerative endangeiitis, similar to acute endocarditis, most frequently occurs in the aorta and the pulmonary artery and is usually associated with infective endocarditis of the semilunar valves. It has also been described in the larger and medium-sized branches of the aorta and the pulmonary artery. The lesions usually assume the form of warty eminences, composed of a cellular and vascular granulation tissue and capped by thrombotic deposits. There is more or less cellular infiltration into the tissues of the vessel wall near such warty outgrowths, and at times the process assumes more of an ulcerative and destructive type. Osler has described an interesting instance of multiple mycotic aneurisms of the aorta the result of infective endaortitis associated with acute infective endocarditis. Schmey has recorded the sudden development of aneurisms, one upon the radial artery and one upon the posterior tibial, in a boy of twelve with acute articular rheumatism, showing that in all probability the microbe or toxin of this disease may also cause this rare form of endarteritis. Such aneurisms, although not embolic, belong etiologically in the same general category as the embolic-mycotic aneurisms just referred to as caused by embolic destructive arteritis. Oliver demonstrated B. anthracis in an ulcerative aortitis.

It is now recognized that the acute and chronic forms of arteritis occur in various infectious diseases—typhoid fever, smallpox, scarlet fever, measles, acute articular rheumatism, influenza, pneumonia, syphilis, tuberculosis, and leprosy. In the acute forms cellular infiltrations, generally circumscribed, are found in the outer coats of the vessels together with more or less extensive proliferation of the subepithelial connective tissue of the intima. Nodular and more diffuse accumulations of lymphoid and epithelioid cells occur beneath the epithelium. These changes are explained as due to the circulation in the blood of the microbes and the toxins of the diseases mentioned. When the endarterial changes result in destruction of the living epithelium thrombosis takes place, and if it is in a larger vessel a typical verrucose endarteritis may be established. The endarteritic lesions are due to a direct implantation of micro-organisms upon the intima in the same way as infections of the endocardium take place; inasmuch as bacteria are often absent, it seems that endarteritis may be caused by toxins also. These changes occur probably more frequently in the veins than in the arteries. Arterial thrombosis in the diseases mentioned is often referable to infectious arteritis.

It is quite evident that there might be more or less difficulty in distinguishing between toxic and infectious verrucose endarteritis and thrombo-arteritis pure and simple. The formation of a parietal thrombus upon a rough spot or thickening of the intima might induce small nodular outgrowths of new tissue. The presence of microbes in the thrombus would indicate that the acute and destructive changes in the walls of the vessels were primary.

In many instances of multiple venous thrombosis it is not unlikely that an infectious or toxic endophlebitis is the primary change in the vessel wall. In typhoid fever, diphtheria, variola, influenza, and other infectious diseases there is found a nodular, sometimes a more diffuse, accumulation of lymphoid and epithelioid cells in the intima, even more frequently than in the arteries. Many of the large cells in such foci seem to have marked phagocytic properties (Mallory). The accumulated cells, as well as the epithelium, may undergo necrosis and become the starting-point of a thrombus. Inasmuch as bacteria are often absent, it would seem that the vascular lesion may be caused by toxins—a toxic endangeitis.

Lancereaux and others believe that there is a malarial aortitis which occurs in the form of gelatinous plaques, situated generally in the ascending part of the arch of the aorta; the lesion is described as beginning in the adventitia with cellular infiltrations which result in atrophy of the media and an adaptative thickening of the intima. Saccular aneurisms may result. It seems that there would be great difficulty in distinguishing between malarial aortitis and nodular sclerosis from other causes.

Experimentally aortitis has been produced by the injection of various microbes—B. typhosus, B. diphtheriæ, streptococcus, etc.—sometimes with and sometimes without previous traumatism to the artery by means of a probe inserted through the carotid. The French especially have been interested in this work (Gilbert and Lion, Therèse, Crocq, Pernice, Boinet and Romary). In some cases the lesions were vegetative, in others gelatinous plaques due to endarterial proliferation resulted. Infiltrations about the vasa vasis were often present. Nodular thickenings are described by Boinet and Romary as following the injection of toxins, of lead, urate of soda, and phloridzin, with or without preceding injury. In their later stages the lesions would be identical with nodular arteriosclerosis.

Metastatic abscesses in the walls of arteries are rare. Virchow observed one in the beginning of the pulmonary artery; and Eppinger describes an abscess, the size of a walnut, in the posterior wall of the aorta just distal to the origin of the left subclavian artery. Andral describes a case of multiple abscesses, of the size of hazelnuts, in the wall of the aorta, but there is some doubt as to the real nature of this case. Spengler describes an abscess in the wall of the aorta just above the semilunar valves.

Consecutive Exudative and Suppurative Angeitis.—While blood-vessels possess considerable resistance against the invasion of suppuration from without, so that in large abscesses it is not unusual to find the vessels wholly freed from the surrounding tissue and bathed in pus, yet periarterial and periphlebitic infiltration and proliferation are common consecutive lesions. This occurs in the vessels at the base of the heart in acute exudative pericarditis, pleuritis, and mediastinitis; the adventitia is then the seat of an œdematous, sero-purulent, and purulent infiltration. And suppurative and necrotic processes around blood-vessels may extend not to the adventitia only, but also to the media and the intima, causing necrosis of the epithelial lining and secondary thrombosis. In this way also may develop suppurative thrombo-arteritis and thrombo-phlebitis. The weakening of the wall of arteries caused by the purulent disintegration of the media sometimes results in another form of aneurismal dilatation—erosion aneurism produced by a kind of hernia of the inner coats at the point of least resistance. This result of consecutive peri- and mesarteritis is especially frequent in the branches of the pulmonary artery that are exposed upon the floor and the trabeculæ of phthisical cavities. The aneurismal bulging takes place upon the side of the artery that is least supported by surrounding tissue, namely, that toward the lumen of the cavity. Frequently an obliterating thrombosis prevents the formation of aneurism and removes the danger of hemorrhage under these conditions. Suppuration in a wound, or in an amputation stump, may destroy the granulation tissue formed by the intima in the process of definitive closure of an artery, cause purulent disintegration of any thrombus present, and thus give rise to the much-dreaded secondary hemorrhage of the preaseptic times.

Colin and Flexner describe instances of perforation of the inferior vena cava in amœbic abscess of the liver.

On subsidence of acute inflammatory lesions of this nature, vascular granulation appears in the walls of the vessel, producing more or less extensive fibrous thickening of the various coats with narrowing of the lumen; in case thrombosis has taken place, the substitution of the thrombus by connective tissue may cause occlusion of the vessel. Terminal fibrous changes of this kind do not differ histologically from the lesions of many primarily productive forms of angeiitis.

Productive Angeiitis.—Inflammation of blood-vessels resulting in the production of new tissue is a frequent form In productive or obliterating endarteritis and endophlebitis there occurs a proliferation of the cellular elements of the intima, which leads to thickening of the intima, eccentric narrowing of the lumen, and eventually to complete occlusion. This process is observed under a variety of conditions. The occlusion after birth of the ductus arteriosus and the umbilical vein and arteries is accomplished by the formation of connective tissue by the intima; as the pressure of the blood in these vessels fails, a degree of contraction ensues that favors the filling of the vasa vasorum; in the narrowed lumen a small thread-like thrombus may form which is finally substituted by fibrous tissue. Similar changes occur in occlusion following ligature, and in the narrowing of the lumen of vessels the capillary bed of which has been restricted (amputations, indurative processes in the lungs, etc.). In these conditions there is usually atrophy of the media. A ligated vessel may be occluded by intimal proliferation without thrombosis taking place; in many cases a thrombus forms, which is then replaced by granulation tissue. In the old and feeble, especially when the arteries are sclerotic, the intima may have lost its power of proliferating and then there is danger of secondary hemorrhage.

Productive Thrombo-Arteritis.—The presence in an artery of a thrombus, whatever the cause of the thrombosis may have been, or of an embolus, is sooner or later followed by reactive changes on the part of the vessel wall, which result in the production of a vascular granulation tissue, provided destructive infection does not occur. The plug becomes infiltrated with leucocytic phagocytes and with fibroblasts. The amount of new tissue and the rapidity with which it is formed will depend more or less upon the age of the patient and upon the previous condition of the walls of the artery in question. The vessels of the aged, the walls of aneurisms and of sclerotic arteries are often so changed and degenerated that but slight or no reactive proliferation takes place under conditions that in young healthy arteries are followed by vigorous growth of new tissue. The vessels present in the new tissue result in part from ingrowth of vascular sprouts from the vasa vasorum, in part from the epithelial cells of the intima. In case the lumen of the artery is but partially occluded, then the tissue replacing the thrombus or embolus gives rise to various forms of intimal thickening—flattened elevations, projecting ridges and bands, cord-like networks. Complete occlusion of the artery may be followed by cicatricial obliteration of the lumen, or the new tissue may be so traversed by vascular spaces that the continuity of the lumen in some measure is restored. (For further details concerning connective-tissue substitution of thrombi, see article on *Thrombosis.*)

In the healing of wounds of arteries and veins a thrombus composed of blood plates and of fibrin first forms, which is subsequently replaced by new fibrous tissue.

Productive Thrombo-Phlebitis.—Productive inflammatory changes occur in the walls of veins after thrombosis. The process pursues the same general course as thrombo-arteritis. It is observed especially in the periuterine veins, the veins of the lower extremities, the pelvic veins, and the sinuses of the dura, which constitute those parts of the venous system that are most frequently the seat of thrombosis. The residues of connective-tissue replacement of a venous thrombus may be fibrous bands coursing across the lumen, the interior of the vein resembling that of a dural sinus, more diffuse intimal thickenings, and great shrinking of the part of the vein involved with complete obliteration of the lumen. Such changes may occur also in the larger veins, such as the venæ cavæ. I refer with more detail to occlusion of the superior vena cava in the section devoted to tumors of the vessels.

Obliterating Endophlebitis of the Hepatic Veins.—An obliterating, proliferative phlebitis occurs in the main stems of the hepatic veins. This process has recently been studied by Chiari. In seven cases collected by Chiari there were periphlebitic proliferative processes or thrombosis followed by productive thrombo-phlebitis. Chiari describes three instances of an apparently primary obliterating phlebitis of the main stems of this vein, which on account of the resulting circulatory disturbances became the cause of death. The endophlebitic process was situated in the proximal portions of the veins with peripheral extension in one case. The tendency to obliteration was marked, leading to mechanical obstruction and fateful secondary thrombosis. The condition is undoubtedly a peculiar one, possibly of syphilitic origin; in one case it was associated with similar changes in the coronary arteries.

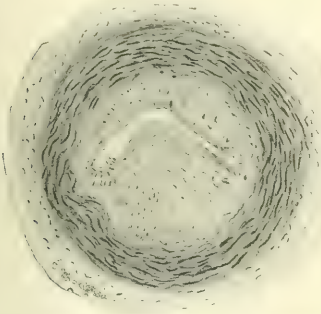

FIG. 627.—Obliterating Endarteritis in Chronic Salpingitis. Hæmatoxylin and eosin. 100.

Consecutive Productive Angeitis.—Inflammation, acute and chronic, generally takes place in the walls of all arteries that lie in tissue the seat of inflammatory processes. In this case cellular infiltration and proliferation extend into the vessel wall from without inward, and all the coats may in time become fibrous; the thickening of the intima caused by the proliferation of fibroblasts and the formation of new fibrous tissue is generally pronounced and complete obliteration of the lumen may take place. In many instances the formation of fibrous tissue in the intima of vessels in organs the seat of chronic fibrous processes is undoubtedly in some measure the result also of obliteration of portions of the capillary districts of the vessels (Thoma), the resulting narrowing of the lumen partaking of an adaptative nature—a localized form of secondary angeio-sclerosis. Changes of this general character are seen in chronic interstitial inflammations and fibrotic processes in the parenchymatous organs, as in interstitial nephritis, orchitis, etc. (Fig. 627). They are well marked in the specific granulomatous processes, and the resulting arterial lesions need not always necessarily present any specific characteristics. The acute stages can be studied nicely in the pial arteries in tuberculous leptomeningitis. There is leucocytic infiltration of the adventitia, extending into the media and intima; the wandering cells are seen making their way between the fibres of the media and through the fenestrations of the internal elastic coat, the nuclei being drawn out long so as to pass through narrow spaces; the elastic coat at times becomes broken through by the cells which may accumulate under the epithelium; simultaneously fibroblasts appear, especially in the subepithelial layers of the intima (see Tuberculous Arteritis) (Fig. 628). Similar changes of a more chronic but non-specific character are seen also in the walls of arteries and veins in chronic tuberculous areas and cavities in the lungs. Great narrowing of the lumen and even closure may result from the newly formed fibrous tissue in the intima. Quite similar changes occur in syphilitic lesions, and it is probable that an isolated, primary, histologically non-specific, productive endarteritis is often caused by syphilis. In productive endarteritis of whatever cause, fibrillar connective tissue interspersed with elastic elements is formed in the intima. At times a distinct, new, elastic membrane develops; it is generally thinner than the original elastic layer, the general course of which it imitates, and it forms the inner boundary of the new, greatly narrowed lumen. But the process is not thereby brought to a standstill, as new fibrous tissue may again form and completely occlude the vessel.

The fibrous perivascular changes that develop in connection with productive angeiitis of diffuse character lead to obliteration of the perivascular lymph spaces and serious obstruction of the lymph flow, which in some tissues, as for instance the brain, may produce grave disturbances of the function and the structure of the special cells.

Acute endarteritis may in time give rise to fibrous nodules upon the intima and to more diffuse thickening. Fenger describes an extensive polypoid fibrous endarteritis of the pulmonary artery associated with valvular endocarditis. The polypoid outgrowths, which almost close the lumen, sprang from the deeper layers of the intima. Willigk described numerous, small pedunculated vegetations. Eriksen noted large radiating scars, producing annular stricture, in the stem of the pulmonary artery, and Willigk found a stenosis of the right pulmonary artery, the lumen being reduced to a diameter of 2 mm.

Goebel describes a local endarteritis that gives rise to small elevations in the intima. The process involves only the intima. The resulting thickenings are based upon the elastic coat and are composed of a network of fibrillæ and elastic elements apparently splintered off from the elastic layer; the nodules are partly vascular. As they become polypoid, thrombosis may result and cause gangrene, which was the case in an instance of spontaneous gangrene in a child, one and a half years old, that forms the basis for his study. Goebel found similar nodules in medium-sized arteries in three of twenty children examined for this process. The cause is obscure; possibly some form of traumatism may be the underlying condition. Syphilis was excluded. It may be added by way of suggestion that a local toxic or infectious endarteritic process might result in such elevations.

Elastic Fibres in Endarterial Proliferations.—The newer methods of staining elastic fibres, elaborated by Tänzer and Unna and by Weigert, have resulted in the demonstration that they are present to a greater extent in the endarteritic proliferations than was formerly thought. Langhans believed that the pre-existing elastic layer—the elastica interna—underwent hypertrophy. Heubner found that in arteriosclerosis the inner layer of the elastica becomes granular, and that in the later stages of the disease four to eight or more elastic bands appeared in the thickening of the intima; in syphilis a new elastic membrane formed near the lumen in the quiescent stages; Heubner derived the new elastic elements from the epithelial cells. Wendeler pointed out that in syphilis each period of growth in the intima closes by the formation of an elastic membrane. Dmetrieff shows that in arteriosclerosis the newly formed elastic fibres in the intima

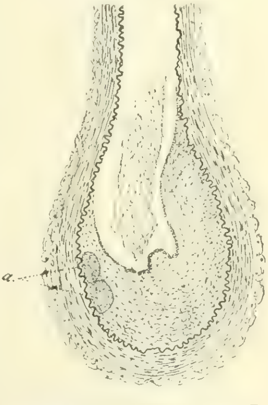

FIG. 628.—Chronic Endarteritis in Chronic Tuberculous Meningitis. *a*, Blood spaces. 150 diameters.

have the same general course as the fibres of the media (see Fig. 629). Jores holds that elastic fibres are formed in two ways: the one is due to the splitting up of the internal elastic layer into several lamellæ, some of which may appear as quite independent bands. This process occurs especially in arteriosclerosis and probably to some extent under normal conditions. But the new formation of fine fibres is by far the most important. Jores favors the theory that these fibres are formed by the secretory activity of the young connective-tissue cells, although it cannot be said that the origin of elastic elements from chemical changes in the collogenous intercellular substances has been wholly disproved. In intimal proliferations Weigert's elastic-fibre stain shows that the new fibres appear first as finer granular lines that surround the cells as a fine network. The epithelial cells do not seem to play any part in this process, inasmuch as elastic fibres never appear between the individual epithelial cells, but are always confined to the subepithelial layers. From observations on ligated vessels Jores found that new elastic fibres are formed more numerously in vessels subjected to the pressure of the circulating blood than in parts enclosed between two ligatures or in vessels the seat of thrombo-arteritis. Hence he regards the new formation of elastic fibres as distinctly compensatory in character. The cells in intimal proliferations are gifted with greater powers to form elastic fibres, directly or indirectly, than the cells of the media.

Malkoff and Gardner hold that the elastic fibres develop in the outer layers of the cell bodies.

In typical endarteritis obliterans there is not much change in the elastic elements, which maintain the same relation in endarteritis obliterans as in productive thrombo-arteritis. In arteriosclerosis, on the other hand, the intimal thickening occurs in layers separated by elastic fibres (Falta).

Obliterating Endarteritis and Spontaneous Gangrene.—The occurrence of obliterating endarteritis in an independent, primary form has not been established upon a satisfactory basis. Its occurrence as a secondary process in indurative processes, in the organization of thrombi, and as the result of consecutive and specific arteritis is generally recognized since Friedländer, in 1876, first called especial attention to endarteritis obliterans. Heubner interpreted endarteritis of the cerebral vessels as always a specific syphilitic lesion, but Baumgarten showed that not endarteritis obliterans is the specific form of syphilitic vascular disease, but gummous arteritis, in which the changes in the adventitia are equally if not more prominent than those in the intima. The endarteritis obliterans observed as the case of spontaneous gangrene in the middle-aged and the young is regarded by von Winiwarter, von Schrötter, Borchhardt, and others as a distinct and primary disease. This opinion is based largely upon the fact that premonitory symptoms, indicative of gradual occlusion of the arteries, may exist a long time before culminating in gangrene, the more prominent symptoms being pain, cyanosis, and coldness. In some cases the complex of symptoms called by Charcot "intermittent claudication" has been present. The arteries more frequently involved are those of the foot, leg, and forearm. The endarteritis, which is described as typical, with vascularization of the new tissue in the intima and reduplication of the elastic coat, begins in the peripheral branches. The adventitia may be greatly thickened, and in some cases the neighboring veins and nerves were found extensively involved in the perivascular sclerosis. In many cases thrombosis or pigmentation, the probable result of thrombosis, was present, and Thoma, who does not believe there is a special form of obliterating endarteritis, holds that the endarteritic changes in this form of gangrene result from the replacement by connective tissue of thrombi in sclerotic vessels. Zoege von Manteuffel claims that the gradual occlusion is brought about by the deposition and organization of successive layers of parietal thrombi in primarily sclerotic arteries. Von Recklinghausen describes hyaline thrombi in the smaller arteries of limbs the seat of spontaneous gangrene. Haga regards endarteritis thrombotica as syphilitic. Hoegersted and Nemsen find that parietal thrombi in sclerotic arteries may result in occlusion and constriction of the vessels. Falta has described cases of gangrene in old people as due primarily to arteriosclerosis associated with an apparently independent productive process in the intima. Goebel attributed spontaneous gangrene in a child, one and a half years old, to thrombosis at the bifurcation of the popliteal artery produced on account of the presence of small globular elevations composed largely of elastic elements and caused by a local endarteritis of obscure origin. The conditions that may produce spontaneous gangrene not caused either by embolism and secondary thrombosis or by arteriosclerosis and thrombosis are consequently rather complicated. Undoubtedly many instances result from arterial thrombosis secondary to the endarterial inflammatory changes that occur in various infectious diseases (see *Gangrene*).

ANGIOSCLEROSIS.—*Definition.*—It is quite impossible to give a comprehensive definition of angiosclerosis, because as at present used this term, and the more common term arteriosclerosis, undoubtedly include processes of different nature. Angiosclerosis is, to say the least, a complex process that appears under different conditions in varying stages and varying distribution. The general idea conveyed by the term is fibrous thickening and other changes in the intima consequent upon changes of a degenerative nature in the media of arteries and veins. When the process affects arteries, and that is by far its more prominent, more important, and more frequent localization, it is known as arteriosclerosis; and sclerotic changes in veins constitute phlebosclerosis. In cases of diffuse sclerotic changes in the vessels both arteries and veins are often involved, but the arterial changes are the more conspicuous both from the clinical and from the anatomical points of view.

The term arteriosclerosis was introduced by Lobstein over fifty years ago; he regarded the process as the result of nutritive disorders in the vessel wall incident to age and use. The word atheroma is used by some as almost synonymous with arteriosclerosis, but in reality atheroma is applicable only to certain late stages of the process, as it affects the aorta and its large branches. In the text-books of pathological anatomy of fifteen to twenty years ago arteriosclerosis is described generally under the heading endarteritis chronica deformans s. nodosa, and phlebosclerosis is mentioned sometimes as endophlebitis chronica deformans s. nodosa; these terms were introduced by Virchow; they are now rarely used. Other quite synonymous names are arteriocapillary fibrosis, introduced by Gull and Sutton, and arteriofibrosis. Since Thoma's epochal investigations, the terms arteriosclerosis, phlebosclerosis, and angiosclerosis are used quite universally. Atheroma should not be used as synonymous with arteriosclerosis.

Pathogenesis and Histogenesis.—Through the investigations and theories of Thoma and his students, angiosclerosis, in some of the phases of its genesis, has been placed upon the same basis as certain processes that occur in the vessels, especially the arteries, under normal physiological conditions.

The physiological paradigm of angiosclerosis is seen in the changes that take place in the aorta immediately after birth. At birth there is no connective tissue in the intima of the aorta. Immediately after birth the circulation in the umbilical arteries ceases; a part of the territory of the aorta is cut away, the aorta is now too large in comparison with the area it supplies with blood, and the circulation in it becomes slower. Under these circumstances connective tissue develops in the intima of that part of the aorta between the ductus arteriosus and the hypogastric arteries, and in this way its lumen is reduced to a size commensurate with the rate of blood current best suited to the needs of the tissues for nourishment. Later in life similar changes occur normally in the carotid, for instance, because from the eighth to the tenth year the growth in strength of this artery does not keep pace with that of other vessels; hence it dilates, its lumen becomes so large that slowing of the circulation takes place, and new tissue develops in the intima until the current reaches the normal flow (Sack). Similar changes take place in arteries after amputation and in arteries whose capillary area is destroyed by disease. The connective-tissue formation in these cases is therefore spoken of as compensatory, calculated to reduce the lumens of the arteries to their proper size.

From these and other observations the general theory is deduced that every slowing of the blood current in the arteries and veins of man that is not completely and at once remedied by a proportionate contraction of the media, leads to a new growth of connective tissue in the intima, which narrows the lumen of the affected vessel, and thus restores the normal swiftness of the blood current more or less completely (Peabody). It may be said here that the compensating endarteritis is regarded as the result of mechanical and chemical changes that occur in and about the cells of the intima of the part of the artery affected; it is not claimed that the compensating proliferation is distinctly and purely teleological in its nature. In order to explain the new growth in the intima, Thoma has elaborated a rather complex theory according to which the irritation produced by the abnormal conditions upon the vaso-motor nerves connected with Vater-Pacini's corpuscles in the adventitia, leads to functional disturbances and hyperæmia of the vasa vasorum and eventually to new tissue in the intima. But intimal thickening occurs in vessels that have no vasa vasorum when the current is supposed to be slower than normal.

The origin of the new tissue in the intima is traced partly to the epithelial cells (Baumgarten, Thoma), partly to the connective-tissue cells in the subepithelial layer. The latter are probably the more important factors in the process. Ingrowth of connective tissue from the media and of vessels from the vasa vasorum is also mentioned as possible by some writers.

The weakening of the wall and consecutive local or general dilatation that gives rise to compensatory thickening in the intima are regarded as the result of wear and tear, of strain, of heightened intravascular pressure, and of toxic and infectious influences. These factors may operate singly or in combination. The obliteration of capillary areas and the narrowing of smaller, peripheral vessels are also held to induce thickening in the intima of the larger vessels because of the relative abnormal wideness of their lumens under these circumstances, but here it is manifestly difficult to determine the primary events in the process.

Thoma showed by physical tests upon the iliac arteries that weakening and dilatation of the arterial walls may occur in the early stages of arteriosclerosis without evident structural changes in the vascular tunics being present. Other investigators describe structural changes, especially in the elastic elements, that surely give rise to loss of strength and elasticity in the arteries affected.

Weiszmann and Neumann, Zwingmann, and others described tears in the elastic lamellæ and granular disintegration of the elastic fibres of the aorta in arteriosclerosis. Manchot observed similar changes in the aorta in the wall of aneurisms. Eberhardt was inclined to attribute the changes described as artefacts due to the use of alcohol not wholly free from water in the staining method then employed, in which fuchsin was the principal ingredient. Eberhardt found, however, that the changes described occurred to a slightly greater extent in the elastic lamellæ and fibrous network of the artificially distended than in the non-distended carotid artery.

Hilbert found that tears or transverse ruptures of the internal elastic coat occur at all ages in the arteries near the heart (aorta and carotids); in youth they are rare in the external iliacs, but after the fourth decennium they are frequent here also. In the renal and similar arteries ruptures are rare at all ages. Internally to the ruptures may be one or more layers of evidently modified or new elastic fibres. In the iliacs he noted a marked separation or splintering of the internal elastic layer in aortic insufficiency. The ruptures that he describes are attributed to momentary increase in the blood pressure under sudden physical exertion or mental excitement. They occur also in hypertrophy of the left ventricle and in cases of probable diminished resistance on account of nutritive disturbances. Sclerosis and aneurisms may result.

By means of more improved technical methods, Dmitrijeff has recently studied the changes in the elastic elements of the arterial wall in arteriosclerosis. He finds that the principal change in the media is a granular disintegration of the elastic fibres, which begins first in the inner parts of the media in the network between the elastic lamellæ. The granules appear in chains, and stain, some well, some poorly, with acid orcein. Later, changes appear in the lamellæ, which stain irregularly and break up into irregular pieces. The chemical nature of the elastic elements changes in some way and they become basophilous; Unna's modified elastin, elacin, is present. These are the earliest changes in the vessels and occur especially in advancing years; Dmitrijeff found them also in the aorta of an eight-year old child that died from scarlet fever. At the same time nodules or more diffuse thickenings appear in the intima, composed of fibrous tissue and new elastic elements arranged either as lamellæ or as networks of fine elastic fibres; this new formation easily undergoes degeneration (atheromatous changes), so that in arteriosclerosis there is degeneration of and new formation of elastic fibres. Foci of inflammation and proliferation in the adventitia and the media also lead to destruction of the elastic fibres in their vicinity. Peri-arterial and mesarterial inflammatory infiltrations about the vasa vasorum were regarded as of great importance by Köster, Huchard, and others. The etiology of such foci is probably to be sought in toxic and infectious influences. Martin and other French writers go so far as to advocate that the degenerative (atheromatous) changes in the large arteries are the result of sclerosis of the vasa vasorum.

Malkoff, from the experimental study of the effects of crushing and stretching of the carotid artery, concludes that injuries of various kinds produce changes in the walls of the arteries that render the wall less resistant and dilatations are produced; but after a time the lumen may be narrowed again by a growth of connective tissue and elastic elements in the intima and also in the media; the lumen may become even narrower than before the injury. The experiments were not extended over a period of time sufficient to disclose the ultimate results.

But in angiosclerosis the compensatory proliferation of new tissue in the intima is sooner or later followed by more pronounced degenerative changes. The new tissue is not able to maintain its integrity in the face of the constant strain of the intravascular pressure and of the inadequate facilities for nutrition. Hyaline and fatty changes take place in the deeper layers of the intimal thickening and in the inner layers of the media. Complete disintegration into fatty and granular débris mixed with cholesterin tablets and crystals of fatty acids give rise to smaller and larger foci of softening that have been termed atheromatous abscesses. By extension the overlying tissue may be destroyed, and defects arise in the intima—"atheromatous ulcers"—upon the rough surface of which fibrin may be deposited. Petrification often takes place in the degenerated tissue and calcareous plates and irregular masses form in the intima and inner layers of the media. True bony tissue has also been found to develop. It is to this degenerative stage of arteriosclerosis, which is seen best in the aorta and its larger branches, that the term atheroma is frequently applied. In advanced cases the sclerotic, degenerative, and petrifying changes are present in varying degrees and produce great deformity, unevenness, and changes in the normal color of the intima and irregular dilatations of the vessels. The relation of arteriosclerosis to aneurism and of phlebosclerosis to varicosity of the veins is elaborated under these respective headings.

Etiology.—The etiological relations of angiosclerosis are ill defined. So far it has not been possible to produce experimentally sclerosis of vessels of animals comparable to the human disease, except possibly the gelatinous nodules in the aorta that French investigators describe after the introduction of bacteria and of toxic substances with or without preceding injury to the intima; these nodules resemble the lesions of nodular arteriosclerosis. Angiosclerosis is rarely observed in animals; it has been seen mostly in old cattle and in old horses.

According to Edgren's statistical study of arteriosclerosis, syphilis, alcoholism, and old age are the predominating factors in its production. Henschen, in his criticism of Edgren's work, points out that the source of the material for such studies must be carefully scrutinized because conclusions based upon the presence of arteriosclerosis in the inmates of institutions that harbor especially syphilitics, alcoholics, or old people naturally will be one-sided and misleading. Such studies usually take no note of the form of arteriosclerosis present.

Angiosclerosis occurs so commonly in advanced years that it is generally regarded as a sort of involutional change; this is true especially of the senile form of arteriosclerosis. It is thought that the media gradually loses its elasticity; dilatation and the formation of more or less new tissue in the intima followed by degeneration take place. According to Thoma a moderate degree of thickening of the intima is frequent after the thirty-sixth year, especially in the peripheral arteries.

The period of life at which a well-marked arteriosclerosis appears and the extent that it may assume are dependent upon the natural, inborn resisting power of the muscular and elastic elements of the arterial wall and upon the amount of wear and tear to which the vessels are subjected. The tendency seen in certain families to the early development of arteriosclerosis is explained as due, at least in part, to an inherited weakness of the arterial walls. This theoretical conclusion has received as yet no confirmation in the form of demonstrable anatomical deviations from the normal in the structure of the arteries of such individuals. On the other hand, there are cases recorded in the literature of centenarians with smooth and normal vessels.

Changes similar to arteriosclerosis have been described in the vessels of children and young persons. Von Schrötter enumerates several recorded instances; Young described sclerosis of the temporal artery in a child of fifteen months; Meigs of the left coronary artery in a child of five months; Gee described aneurisms of the coronary arteries and atheromatous changes in the aorta in a child of seven years that died from dropsy and pneumonia following scarlet fever; and Chiari observed sclerosis of the aorta with typical histological changes in a boy of thirteen years, the disease being attributed to abuse of tobacco and alcohol. Seitz found seventeen cases of arteriosclerosis between ten and twenty-seven years of age out of one hundred and forty-eight cases of arteriosclerosis examined post mortem. Durante has described an instance of calcification of the inner layers of the tunica media of the pulmonary artery and the aorta in a prematurely born infant that lived only a few days. He regards this as an example of a congenital atheroma. The parental history of the infant was unknown; death resulted from peritonitis due to infection of the navel.

It is of course doubtful whether the sclerotic changes in the vessels of children and young persons depend upon a general primary weakening and loss of elasticity and contractility of the media. Special toxic and infectious influences may be at work in such cases, the sclerosis being the result of inflammatory and other lesions in the media.

Statistics show that men are more frequently affected with angiosclerosis than women. Edgren's statistics give twenty-one per cent. of arteriosclerosis in women and seventy-nine per cent. in men. Arteriosclerosis apparently develops later in life in women than in men.

Chronic intoxications and infections of various kinds are regarded generally as playing an important part in the etiology of angiosclerosis, but so far it has not been possible to make any etiological subdivisions of the disease. Among the intoxications those due to alcohol, lead, and gout are of the first importance. Tobacco is regarded by clinicians as not entirely free from deleterious action upon the arteries; Huchard thinks it exercises a special influence upon the coronary arteries. The precise mode of action of these substances can hardly be more definitely specified than that under the toxic influences degenerative changes and weakening develop in the arterial wall, especially the media. Martinotti claims to have produced changes in the renal and cerebral arteries resembling arteriosclerosis by the injection of camphor, alcohol, and turpentine.

Of the chronic infections syphilis is the most important. Edgren places syphilis first in the etiology of arteriosclerosis, which when due to syphilis tends to appear rather early in middle life. Arteriosclerosis upon a syphilitic basis does not appear to present any special features (see Syphilis of the Vessels, page 105).

Infectious diseases in general appear to exercise a harmful influence upon the muscular and elastic parts of the walls of blood-vessels. Reference has already been made to the toxic and infectious forms of angeiitis and to the production of gelatinous plaques in the aorta by the injection into animals of bacteria and toxins. The closure of the vasa vasorum by inflammatory changes in the adventitia and the outer layers of the media would surely interfere with the proper nutrition of the inner layers of the wall. Thoma has shown that the strength of the arterial wall suffers in diseases of the most various kinds.

The overfilling of the vascular system due to excessive eating and drinking and the increased pressure and strain upon the arteries in muscular work constitute another group of causes (Osler). According to Huchard and Edgren arteriosclerosis is inseparably connected with the pathogenesis of increased pressure. The relation of angiosclerosis to the intravascular pressure is seen in the distribution of the disease in the vascular system.

Arteriosclerosis sustains a double relation to renal disease. An existing sclerosis of the renal and peripheral arteries may interfere with the nutrition of the renal parenchyma to a degree that parenchymatous degeneration and connective-tissue overgrowth result. On the other hand, a primary interstitial nephritis by raising arterial pressure may lead to connective-tissue growth in the intima.

The Forms of Arteriosclerosis.—There is some confusion in the classification of arteriosclerosis. The various anatomical forms often are found connected by transitional stages. Thoma recognized two main forms, diffuse or secondary, nodular or primary. The former he regarded as due mainly to primary changes in the peripheral vessels and the capillaries and as consecutive to the increased peripheral resistance. The latter he regarded as the result of primary changes of a degenerative nature in the media, and as localized especially in those regions where the pulse wave is high and strong. Councilman holds that the diffuse form is a distinct disease associated with widespread changes in the media, and he distinguished a third form, the senile arteriosclerosis, in which the lesions are mainly degenerative, compensatory thickening in the intima being but little marked.

Senile Arteriosclerosis.—In this form the process is largely one of degeneration and calcification with but little thickening in the intima. It represents the general atrophy and degeneration of senility as they affect the arteries when even connective tissue has lost much of its power of proliferation. In this form the heart is not always hypertrophied; atrophy of internal organs may be marked. The aorta and its larger branches are dilated irregularly, tortuous and elongated, the walls in general thinner than normal, stiff, and covered by calcareous plates or the seat of cavities containing grayish-yellow, grumous material—the detritus of degenerated, necrotic muscular and fibrous tissue. The cavities are sometimes called atheromatous abscesses; frequently the thin internal membrane is ruptured and rough spots and areas arise ("atheromatous ulcers") in the floor of which calcification may take place or thrombotic material accumulate. In typical cases the aorta and other large vessels are changed into rigid calcareous tubes, the inner surface being rough, frequently fissured, and covered by fibrinous masses. The intima has lost its glistening appearance. The resulting deformities of the affected vessels certainly warrant the name arteritis deformans which Virchow applied to the disease.

The relations of senile arteriosclerosis to thrombosis, senile gangrene, cerebral softening, and other consecutive changes in the body are discussed fully elsewhere.

Diffuse Arteriosclerosis.—This is the more important form, and in it the lesions are widely distributed, embracing all the arteries of the body. As pointed out by Councilman, contrary to the senile sclerosis, the subjects of diffuse arteriosclerosis are generally in the prime of life.

In twenty-seven cases of this disease studied by Councilman, the youngest, a negro, gave his age as twenty-three; the oldest was sixty. Most of the cases ranged between forty and forty-five; fourteen were white and thirteen colored. The negro seems disposed to this disease.

In this disease there is a typical pathological picture. Most of the subjects who come to autopsy are strongly built, well-nourished, muscular individuals. As a rule, there is no œdema either of the face or of the lower extremities. When œdema is present it comes on in the last few days or weeks of life. Heart hypertrophy is always present and may reach an extreme degree. In two of Councilman's cases in which there were no valvular lesions whatever, the heart in one weighed 850, and in the other 820 gm. The average weight was over 400 gm. The myocardium is firm and dark. Close examination often shows some degree of fibrous myocarditis, this depending on the degree of involvement of the coronary arteries in the general trouble. The heart hypertrophy may be confined to the left ventricle, but in most cases it is always associated with so much dilatation that the right ventricle also becomes hypertrophied. The dilatation may be so excessive as to affect the integrity of all the valves. Anatomical lesions of the valves are usually absent. There may be some extension of the aortic disease to the aortic valves or to the aortic segment of the mitral valve, but the thickening so produced is not generally sufficient to interfere with the functions of the valves. The supposed inflammatory changes in the myocardium described by Buhl and referred to by Thoma were not found by Councilman. The most marked changes are found in the aorta and the large arteries given off from this. The large arteries are more or less dilated, the dilatation in some cases starting in the aortic orifice and extending throughout the aorta and large arteries. This dilatation is seldom symmetrical throughout, but in addition to the general dilatation there may be here and there mere local dilatations.

The branches of the arch are sometimes relatively more dilated than the aorta. There is elongation of the vessels as well. The aorta makes lateral curves and the normal curves of other arteries are greatly accentuated. In addition to the dilatation there is a general diffuse thickening of the arteries, which is often relatively greater in arteries the size of the radial than in the large vessels. In the large arteries the intima is roughened by projecting elevations, which are frequently distinguished by differences in color and consistency. They may be of a pearly, transparent color and very hard, in both color and consistency similar to cartilage. They may be of an opaque, whitish-yellow color, and the centre soft and pultaceous. On incising such places a soft, white, mortar-like mass escapes. We may find irregular, ragged excavations, often covered with fibrin, showing that the softening has extended through the intima of the vessel during life. Similar areas of softening and degeneration may be found in the diffusely thickened intima. There may be more or less calcification which is usually confined to the projecting elevations, but this never reaches the same extent here as in the senile form. There are frequently longitudinal folds and puckering of the intima as though due to the contraction of the vessel after death.

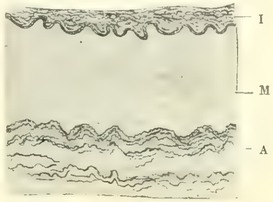

FIG. 629. Diffuse Arteriosclerosis. Renal artery. Weigert's elastic-fibre stain. I, Intima with new elastic fibres; M, media, the seat of hyaline degeneration; no elastic elements; A, adventitia with increased number of elastic fibres. × 150.

The two essential alterations are various degenerative changes in the media and a growth of tissue in the intima. The degenerations in the media are shown in various ways. Sections of the fresh artery show some fatty degeneration, but this does not play the chief part. The most common change seems to be necrosis and hyaline degeneration (Figs. 629 and 630). The muscle cells lose their nuclei and the whole muscular coat is changed into a solid homogeneous mass. The elastic fibres between the muscle laminæ are frequently broken up and disappear; these changes probably appear early in the process. In some sections of the dilated carotid, for instance, the media as such may not be recognized, the whole artery being changed into a dense, thick mass of sclerosed connective tissue. This atrophy of the media is always best marked opposite the points of greatest thickening of the intima. The tissue composing the thickened intima consists of thick layers of dense connective tissue, which not only in consequence of the poor nutrition which it has, but also in consequence of the pressure to which it is subjected, is particularly prone to degenerative changes. The tendency to degenerative changes, however, is not so marked here as it is in the senile form.

This diffuse arteriosclerosis that Councilman describes agrees best with the form which Thoma has described as secondary arteriosclerosis, and in which he considers that the changes in the large arteries are due to the resistance to the blood circulation that the diseased small arteries cause. In a paper on the conditions of the vessels in Bright's disease, which preceded his publication on the arteries, Thoma shows that there is an opposition to the passage of the blood, which is due primarily not to a narrowing of the calibre of the vessels by the thicken-

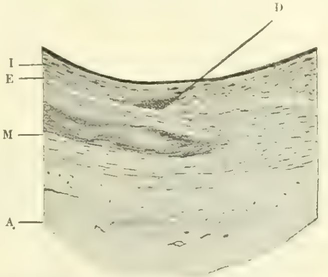

FIG. 630. Sclerosis of Anterior Tibial Artery. Gangrene of foot from thrombosis. I, Fibrous intima; E, elastic lamina; M, media with hyaline degeneration and calcification; A, adventitia; D, beginning degeneration in intimal thickening. Hæmatoxylin and eosin. × 100.

BREGMANN'S TABLE SHOWING RELATIVE FREQUENCY OF ARTERIOSCLEROSIS IN DIFFERENT ARTERIES. THE FIGURES REPRESENT PERCENTAGES.

Normal.		Slight degree.		Medium degree.		Severe degree.		Without distinction in degree.	
Brachial	45	Radial	56	Carotid, internal	48	Aorta, abdominal	16	Ulnar	94
Iliac, external	42	Carotid, external	56	Subclavian	47	Cerebral	15	Tibial, anterior	92
Aorta, abdominal	36	Cerebral	54	Ulnar	39	Carotid, internal	13	Subclavian	88
Aorta, ascending	33	Ulnar	52	Tibial, anterior	37	Aorta, ascending	13	Cerebral	87
Carotid, common	32	Splenic	46	Axillary	36	Subclavian	12	Carotid, internal	87
Femoral, superficial	31	Tibial, anterior	45	Splenic	29	Tibial, anterior	11	Radial	86
Axillary	29	Femoral	44	Carotid, common	28	Popliteal	10	Splenic	82
Carotid, external	22	Popliteal	44	Radial	27	Carotid, common	9	Popliteal	79
Popliteal	21	Aorta, ascending	41	Popliteal	25	Femoral	18	Carotid, external	78
Splenic	18	Brachial	40	Aorta, abdominal	24	Splenic	7	Axillary	71
Radial	14	Iliac, external	38	Iliac, external	19	Carotid, external	6	Femoral	69
Carotid, internal	13	Axillary	34	Cerebral	18	Radial	3	Carotid, common	68
Cerebral	13	Carotid, common	31	Femoral	17	Ulnar	3	Aorta, ascending	67
Subclavian	12	Subclavian	29	Carotid, external	16	Axillary	1	Aorta, abdominal	64
Tibial, anterior	7	Carotid, internal	26	Brachial	15	Iliac, external	1	Iliac, external	58
Ulnar	6	Aorta, abdominal	24	Aorta, ascending	13	Brachial	0	Brachial	55

In this table no distinction is made as regards the kind of arteriosclerosis.

ing of the intima, but by an increased permeability of the vessel walls. With this disease of the vessels there is an increase in the connective tissue and destruction of large numbers of capillaries, still further diminishing the size of the vascular bed, and then comes a disparity between the calibre of the artery and the territory to be supplied, followed by a compensating growth of connective tissue. This endarteritis of distant organs is extended in the same way to the aorta. Councilman would rather take the view that the changes in the aorta and in the minute arteries are due to the same cause; that diffuse endarteritis is a disease primarily due to a degeneration of the muscular fibres of the media. On this the growth of the intima follows, which is due to the same cause acting in two ways: in one, by the well-known law of connective-tissue growth, to supply a defect, in this case the degeneration of the media; and in the other, possibly acting under the law of Thoma, a compensating endarteritis to restore the abnormally dilated vessel to a normal calibre. Thoma's assumption that this secondary arteriosclerosis is due to an increased blood pressure in the aorta from the increased peripheral resistance cannot be proven.

There seems to be good reason for separating the lesions of angiosclerosis from the senile endarteritis and the lesions accompanying it. The senile endarteritis is a disease of advanced life, seldom occurring before the age of fifty. The lesions in the vessels are slow, and there is little reaction to the degeneration. Clinically, there is absence of the high arterial pressure, which constitutes the most obvious clinical manifestation of the disease arteriosclerosis. The diffuse arteriosclerosis is a definite disease; the lesions in the arteries and tissues form a pathological entity, and the primary lesion to which all the changes are due is a degeneration of the tissue of the media of both the large and the smaller arteries.

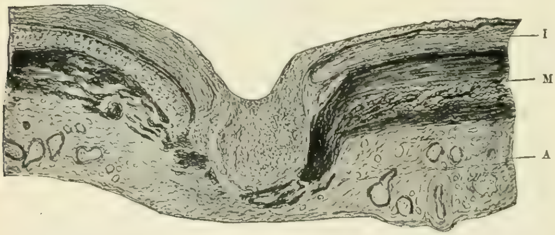

FIG. 631.—Nodular Sclerosis of Aorta with Beginning Aneurism. Hæmatoxylin and Weigert's elastic-fibre stain. The intima (I) is thickened, contains parallel, wavy, elastic fibres, except at the point of the bulging; the media (M) is thinned, degenerated, the elastic broken up; A, adventitia. × 150.

ORDER OF FREQUENCY OF NODULAR AND DIFFUSE ARTERIOSCLEROSIS IN DIFFERENT ARTERIES. (Bregmann.)

Nodular Form.	*Diffuse Form (in Thoma's Sense).*
Abdominal aorta.	Radial.
Common carotid.	Ulnar.
Descending thoracic aorta.	Anterior tibial.
Internal carotid.	Popliteal.
Ascending aorta.	Splenic.
Arch of the aorta.	Superficial femoral.
Cerebral.	Axillary.
Subclavian.	External iliac.
Common iliac.	Brachial.
Cœliac.	Subclavian.
Superior mesenteric.	External carotid.
Inferior mesenteric.	Cerebral.
Renal.	Internal carotid.
Coronary.	Ascending aorta.
Popliteal.	Common carotid.
External carotid.	Abdominal aorta.
Splenic.	
Axillary.	
Common femoral.	
External iliac.	
Posterior tibial.	
Superficial femoral.	
Deep femoral.	
Internal iliac.	
Brachial.	
Anterior tibial (below).	
Ulnar.	
Anterior tibial (above).	
Radial.	

Nodular Arteriosclerosis.—In the nodular or primary form of arteriosclerosis there are seen flat, button-like, hemispherical, yellowish or yellowish-white projections above the intima, especially about the orifices of the arterial branches. This is generally regarded as the result of the greater strain that this part of the artery is exposed to. The areas consist of new connective tissue and new elastic fibres in the intima, the underlying media being either fibrous, calcareous, or degenerated and necrotic. Thoma showed that the cast after filling the vessel with melted paraffin injected under the same pressure as that of the blood came out smooth, showing that in the tense vessel the intimal nodules fill defects in the media. The stage of weakening in the intima antecedent to the intimal thickening is liable to result in aneurism (Fig. 631). The new tissue soon becomes hyaline, fatty changes take place, and eventually disintegration into fat drops, cholesterin, granular detritus gives rise to softening. The degeneration begins in the outer layers of the sclerotic thickening, but may extend inward until the epithelium lining the vessel is destroyed and a larger or smaller rough area due to loss of substance is formed. Calcareous infiltration may take place. More or less leucocytic and round-cell infiltrations occur around softened areas. The adventitia may be unchanged, fibrous, or the seat of foci of cell accumulations.

This form is possibly due to local, circumscribed areas of degeneration and weakening in the media produced by strain, by toxic and infectious lesions. Several French investigators have produced apparently similar plaques in the aorta of animals by injection into the circulation of bacteria, bacterial toxins and other substances, such as lead, uric acid, etc., with or without producing traumatic lesions of the vessel wall. In some cases of this kind the lesions seemed to be the result of proliferation in the intima; in others there were mesarterial and periarterial inflammatory foci about the vasa vasorum.

In goitre of all forms, Jones found degenerative and sclerotic changes in the arteries of the thyroid and its capsule. The changes occurred apart from general arteriosclerosis and were found quite marked in eighteen out of twenty cases examined. The vessels were abnormally friable. The internal elastic coat was granular, broken across, and calcified; in one case it had changed into a calcareous plate; connective-tissue thickening of the intima associated with the formation of new elastic fibres had resulted, followed by hyaline degeneration.

The Distribution of Angiosclerosis.—The relative frequency of angiosclerosis in the different parts of the circulatory system has been studied by Bregmann, Sack, and others. The arteries are more frequently involved than the veins, although the study of phlebosclerosis has been rather insignificant as compared with the amount of attention paid to arteriosclerosis.

Arteriosclerosis in general is more frequent in the vessels of the extremities than in the aorta and its branches of the first and second order; it is most frequent in the arteries of the leg and forearm, beginning first of all in the anterior tibial. This is explained on the score of the general lateral hydrodynamic pressure to which these vessels are exposed on account of posture in addition to the general hydrodynamic pressure.

Arteriosclerosis of the pulmonary artery is exceedingly rare as compared with the frequency of the process in the aorta. In chronic tuberculosis of the lungs, emphysema and other diseases resulting in atrophy and destruction of lung tissue naturally give rise to more or less compensating endarteritis. In Sauné's thesis are collected twelve cases of sclerosis of the pulmonary artery; in seven, emphysema was present. It is suggested by Laache that the carbonic dioxide may tend to prevent the development of arteriosclerosis, although the mode of action is not clear at all; probably the more important factor is the low pressure in the pulmonary artery as compared with that of the aorta (Laache, Frankel, Sauné).

Laache has described an instance of sclerosis with atheroma of the pulmonary artery that clinically presented the symptoms of congenital heart disease ("morbus cœruleus"); there were hypertrophy of the right ventricle, marked nodular condition of the intima, and dilatation of the pulmonary artery. Apparently the sclerosis in this case was due to weakening of the arterial wall. Romberg has described a similar case. He found but one similar case in the literature, a case of Klob's. The striking blueness of the skin in Romberg's and Laache's cases—in both instances it led to diagnosis of congenital heart disease—is difficult to explain.

Huchard and von Schrötter describe each a case of sclerosis in the pulmonary artery associated with pressure upon it by aortic aneurism. Edgren attributes pulmonary sclerosis in one case to patency of the ductus arteriosus.

Phlebosclerosis.—The early observations on sclerosis of the veins were made by Hodgson, Rokitansky, Virchow, and others. Lobstein introduced the term phlebosclerosis. Rokitansky described thickening of the intima and of the adventitia of the veins involved in varicose aneurism; and Virchow called attention to chronic endophlebitis in long-continued passive congestions; in both cases the influence of mechanical causes is quite evident.

According to the careful studies of Sack the localization of phlebosclerosis is determined largely by the same factors as arteriosclerosis, and the tendency is to regard phlebosclerosis in many cases as a systemic disease, analogous to diffuse arteriosclerosis, and due to general nutritional disturbances resulting in weakness of the middle coat. But it may appear as a local disease in consequence of local venous congestions, as, for instance, in the portal system in atrophic cirrhosis of the liver, and in the pulmonary veins in mitral stenosis. As will be seen from the adjoining table of Sack, phlebosclerosis attacks especially those vascular provinces in which the venous pressure varies greatly in different positions of the body, and in which the activity of the voluntary muscles favors the venous flow to relatively but a slight extent. Now every obstruction to the venous flow hinders also the arterial flow, though in a much smaller degree, and undoubtedly phlebosclerosis in some cases precedes arteriosclerosis. Sack showed by the statistical method that the two diseases are closely related. There is need of further study of these questions.

The important relations of phlebosclerosis to varicose dilatations of the veins are discussed under *Varicose Veins.*

Sack's Table Showing the Distribution of Phlebosclerosis.

	Number of bodies examined.	Number with phlebosclerosis.	Frequency of disease in percentages.
V. jugular. int.	20	7	35%
V. brachialis	55	4	7
V. cephalic	6	3	50
V. basilar	7	4	57
V. radial	52	0	0
V. ulnar	58	0	0
V. iliac. ext.	61	23	38
V. femoral	67	51	76
V. popliteal	72	65	90
V. saph. mag.	55	50	91
V. saph. par.	14	13	93
V. tibial. ant.	88	24	27

Sclerotic veins are elongated and of varying calibre. They present constrictions and dilatations, the dilatations amounting in some cases to well-marked pouches filled and distended with blood. In the severer forms of the disease the vessels are curved upon themselves, and if superficial, they can be rolled under the finger like a cord.

The valves are insufficient, either from retraction of their leaflets or from adherence to the side of the vein. When the vein is cut open its walls show differences in thickness, at one point being strong enough, perhaps, to gape open like an artery, at another collapsing as a vein usually does. At times, portions of the veins show calcified plates and ulcerous spots, resembling in each case those so frequently found in arteriosclerosis. The most marked changes take place in the intima and the inner part of the media. The coats are thickened and present points of fatty changes and of coagulation necrosis often infiltrated with lime salts; at other points atheromatous débris may have formed.

Syphilis.—Some of the first observations on syphilis of the blood-vessels, as it affects the arteries at the base of the brain, were made by Virchow and Lancereaux. A good anatomical description of syphilitic arteritis was given by Allbutt in 1868. In 1874 Heubner published a study of fifty cases of syphilis of the cerebral vessels, in which he endeavored to establish a primary endothelial proliferation ("arterioma") as the specific form of arterial syphilis, the virus acting directly on the intima. In this he was opposed by Baumgarten, who, while not denying that syphilis causes endarteritis, yet claimed that the only arteritis histologically characteristic of syphilis begins in the lymph spaces of the adventitia and results in a gummatous periarteritis. Köster, Friedländer, and others supported Baumgarten's view, and

Friedländer regarded Heubner's endarterial proliferation as indistinguishable from endarteritis obliterans in general. According to this view the virus acts principally upon the adventitia through the vasa vasorum and the lymph vessels, the inflammatory process extending inward.

Syphilis of the Smaller Vessels.—At the present time the general teaching is that syphilis of the smaller vessels occurs either as an independent process or as part and parcel of a local syphilitic infiltration; von Zeissel and other syphilologists state that primary vascular syphilis is one of the rare localizations of the disease. In the primary form the vessels involved usually present yellowish-white or grayish thickening of the adventitia and the intima. A smaller vessel, such as a cerebral artery for example, may be studded with translucent or whitish, circumscribed patches, more or less cartilaginous in consistency and non-calcified; or a certain length of the vessel may be transformed into a whitish cord. The tendency to fibrous obliteration of the lumen is pronounced, but in the earlier stages the proliferation in the intima is richly cellular and vascular. This is the syphilitic endarteritis of Heubner. It is now generally held that this form cannot be distinguished either microscopically or macroscopically from certain thickenings of non-syphilitic origin. The occurrence of obliterating endarteritis in circumscribed form in youthful persons is regarded, however—and as unquestionably so when associated with gummous nodules—as in the majority of cases the result of syphilis. The new tissue in the intima may contain vascular spaces. The elastic layer is greatly thickened and folded. Bands of elastic fibres appear in the thickening, and their development is ascribed by Abramow and Haga as due to a splitting up of the old membrane by the growth of fibrous tissue between its layers. But it is also probable that new elastic fibres form; at all events, that is not impossible. A reduplication of the elastic layer is regarded by Wendeler as marking each standstill of the process. The elastic elements do not appear to differ in their behavior from that seen in endarteritis obliterans in general.

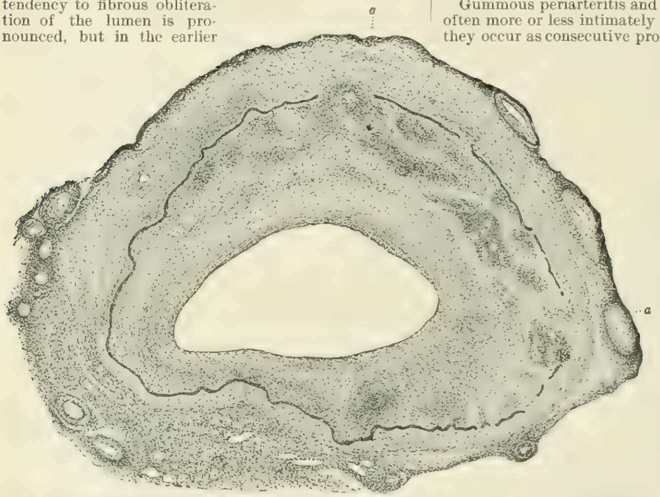

FIG. 632. Gummous Arteritis. Great intimal thickening with small cellular areas—gummata. At *a*, perivascular infiltration of intima. (From Nothnagel's "Specielle Pathologie und Therapie," 1899, xv., p. 147.)

At other times the vessels are surrounded either with nodular, cellular infiltrations or dense cicatricial tissue. In the primary syphilitic lesion there is marked periarterial infiltration, which is surrounded by an external ring of elastic elements, probably part of the walls of the perivascular lymph spaces in which the cellular proliferation takes place. In later syphilitic foci, when the granulation-tissue formation is in the recent stage, there is cellular infiltration in the adventitia, media, and intima. Distinct gummous nodules, either purely cellular (lymphoid and epithelioid cells) or with a granular, necrotic centre and a cellulo-fibrous periphery with giant cells, may be found in the vessel wall (Baumgarten's gummous arteritis), most frequently in the adventitia. This is the only form of syphilitic arteritis that is histologically specific (Fig. 632).

The gummata develop especially in the adventitia, more rarely in the media and the intima. Occasionally a single cross section may show a series of nodules in the various layers of the wall. Later, when fibrous transformation takes place, all the coats become fibroid, the media atrophic.

Gummous periarteritis and productive endarteritis are often more or less intimately associated, especially when they occur as consecutive processes in the midst of syphilitic foci. The different appearances so often observed are explainable in a measure by the degree and the duration of the disease. Syphilitic arteritis differs from arteriosclerosis by its circumscribed occurrence and by the tendency to organization and obliteration; fatty changes and calcification are not characteristic of syphilis.

Most of the investigations on syphilis of the smaller arteries concern the cerebral. The apparent frequency with which the cerebral vessels, especially at the base, are affected by these processes is explained as in part the outcome of the great interest that clinicians take in all the phases of cerebral syphilis, and perhaps also because the basal vessels are constantly bathed in cerebro-spinal lymph. The anterior cerebral arteries—the cerebral branches of the internal carotid—are the ones especially involved. But syphilitic vasculitis as an independent process occurs elsewhere. In the spinal cord both arteries (Marinesco, Pick) and veins (Lamy, Orlowsky) may be involved. The coronary arteries, the arteries of the extremities, the splenic, the retinal, the mesenteric, and the adrenal (Weichselbaum) may be diseased more or less extensively as well. According to Urlich, Palma, and Birch-Hirschfeld, syphilitic changes in the coronary arteries may be primary or consecutive, the left coronary artery being affected more frequently than the right.

In Abramow's cases there were circumscribed nodules in the walls of the arteries of the extremities and of the intimal organs, the cerebral being spared. In some the appearances described by Heubner predominated; in others, a more diffuse cellular infiltration with gummous nodules, especially in the adventitia, the muscular coat showing a granular disintegration. The destruction of the media by cell proliferation beginning either in the adventitia or the intima had resulted in places in aneurismal dilatations. Some of the appearances presented resemble not a little those of periarteritis nodosa.

Von Zeissl, Lomokowsky, and Haga describe syphilitic arteritis of the extremities. In Haga's case the vascular disease resulted in spontaneous gangrene; this form of spontaneous gangrene seems quite frequent in Japan. Haga reports thirteen cases, in all of which the vessels of the affected extremities presented the same changes. The vascular lumen was obliterated either as the result of successive intimal thickenings, due to the production of a vascular new tissue solely, or from thrombosis. The media was thickened. In nine of the thirteen cases there were focal accumulations of round cells about the vasa vasorum, and in some instances cellular nodules were present in the media and the intima (gummous arteritis). Quite similar changes were observed in the veins. Scriba suggests that in some cases this arteritis is the result of congenital syphilis.

Von Zeissl and Langenbeck describe syphilitic arteritis of the brachial artery that was healed by antiluetic treatment.

Syphilis of the Aorta and Larger Vessels.—Isolated instances of gumma in the walls of the larger arteries, especially the pulmonary, have been described by Weber, Wagner, Virchow, and others. Weber describes a gumma as large as a bean in the pulmonary artery, beginning in the media under the intact intima and causing great narrowing of the lumen.

Syphilitic Mesarteritis.—Wagner, Hertz, Backhaus, Doehle, Heller, and others describe a primary syphilitic mesaortitis. Macroscopically the intima presents circumscribed fissured and furrowed areas and depressions, which occur in groups especially at the beginning of the aorta and near the origin of the larger vessels. Elsewhere the intima may be smooth and normal or the seat of sclerotic changes. The media in such areas may be wholly absent or replaced by a thin layer of scar tissue. Microscopically there is proliferation about the vasa vasorum which may show obliterating changes, and there may be more or less distinct gummata with necrotic centres (Heller, Backhaus) as well as cicatricial areas with thickening of the intima and retractions, giving it the peculiar linear and irregular pit-like depressions that are regarded as characteristic of specific mesaortitis. Foci of small-celled infiltration, as well as diffuse fibrous changes, are present in the adventitia. These changes may be combined with ordinary arteriosclerosis. Backhaus states that of ninety-nine syphilitics examined at the Kiel Institute, seventeen showed mesarteritis. Doehle describes a typical case in a syphilitic woman, aged twenty-five. Belfanti describes beginning gummous nodules in the aorta with marked circumscribed thickenings in the intima. Irregular ulcerations in the aorta with callous margins are also recorded as of syphilitic origin. Bollinger has also described a gummous form of endarteritis. All seem to agree that the presence of circumscribed areas of fibrous attenuation of the aortic wall, associated with more or less dilatation, may be regarded as the result of syphilitic mesaortitis; the changes are observed not rarely in rather young persons; there are often distinct syphilitic lesions in other organs, and the changes in the aorta certainly do not correspond to those of ordinary arteriosclerosis. It is upon the basis of such lesions that aneurisms in young syphilitics probably develop. I have seen two cases of multiple, small sacculated aneurisms in the beginning of the aorta that originated in fibrous mesaortitis; in both cases were areas of marked fibrous attenuation without much compensating fibrous thickening in the intima.

Syphilis is also regarded as playing an etiological rôle of a more general nature but of great importance in the vulgar form of arteriosclerosis. The occurrence of arteriosclerosis and of arteriosclerotic aneurism in young syphilitics is rather frequent and is generally known. On account of the many complex factors that enter into consideration in arteriosclerosis the exact rôle of syphilis is hard to define.

Syphilitic Phlebitis.—Much that has been said of syphilis of the arteries is applicable to syphilis of the veins, and especially as regards the secondary changes that occur in smaller veins in the midst of larger syphilitic foci. Dowse briefly refers to obliterative changes in the posterior cerebral sinuses in a gummous pachymeningitis.

Oedmanson, Winckel, and Birch-Hirschfeld described diffuse and circumscribed endophlebitis of the umbilical veins of congenital syphilitics. Schüppel has described a gummous pylephlebitis in congenital syphilis, and Bowman attributes certain cases of thrombosis of the stem of the portal vein to syphilitic periphlebitic changes. Huber found intimal thickening with petrification in the veins of the extremities of a syphilitic girl twenty-two years old.

In *congenital syphilis* there frequently occurs an obliterative vasculitis of the umbilical vessels which was first described by Oedmanson. Schüppel has described peripylephlebitis in a syphilitic infant, and in 1864 Virchow observed an ossifying endaortic process in a girl of eighteen with congenital syphilis. The vascular changes of the lesions of congenital syphilis in the internal organs resemble those of the acquired disease. Reference has been made to Scriba's view that spontaneous gangrene may be caused by an arteritis of congenitally syphilitic origin.

TUBERCULOSIS.—The older pathologists, such as Rokitansky and Virchow, regarded the blood-vessels as immune to tuberculosis. The demonstration by Weigert in 1877 that acute general miliary tuberculosis results from the tuberculous invasion of either a blood-vessel or the thoracic duct put an end to this theory. So thoroughly did Weigert demonstrate this course of events that when the tubercle germ was discovered a few years later he could say truthfully that it was necessary only to substitute bacillus for poison in order to make the report of his investigations conform fully to the new requirements.

Tuberculosis of the walls of blood-vessels may result from the extension of the process from adjacent tuberculous foci. This may occur in the arteries and veins. In case the lumen is not closed by productive endovasculitis and thrombosis, the infiltration in the vessel wall on caseation and disintegration may give off tuberculous material and bacilli to the circulating blood. This leads to embolic or miliary tuberculosis of the corresponding capillary district. In the case of the pulmonary vein, the general circulation becomes infected; in the case of a systemic vein, miliary tuberculosis of the lungs results; and if it concerns an artery, miliary tubercles may spring up in its capillary district. Tuberculous and suppurative destruction from without of the branches of the pulmonary artery exposed in tuberculous pulmonary cavities may so weaken the wall that aneurismal dilatations develop ("erosion aneurism"). Many of the copious hemorrhages in advanced pulmonary phthisis result from the rupture of aneurisms of this nature.

Dittrich, Kamen, and Sigg have described tuberculosis of the wall of the aorta due to direct extension. In Dittrich's case an adherent lymph gland communicated the disease to the thoracic aorta, the intima of which presented an oval defect with elevated ridges, a continuous tuberculous process traversing the aortic wall. Kamen's case was of similar origin, the vessel presenting a dilatation with rupture of the wall. In Sigg's case a tuberculous lung was adherent to the aorta, which presented a bulging corresponding to the caseous replacement of its wall, the caseous area being covered internally by a thrombus.

When tubercle bacilli reach the circulating blood they sometimes become implanted upon the intima of larger vessels such as the aorta. Weigert, Flexner, Hanot and Levy, Stroebe and Blumer have described pinhead-sized intimal, aortic tuberculous masses. Blumer describes two instances of intimal tuberculosis of the abdominal aorta; in one of the cases there were several minute nodules of characteristic structure. The sclerosis of the aorta present in both cases did not play any part in determining this localization. In all of these cases the infection took place directly upon the intima and not through the vasa vasorum or the lymphatics of the walls of the artery. The tuberculous masses appeared as if they had been fastened upon the intima. The surface of such areas may contain tubercle bacilli in large numbers.

According to Cadéac tuberculous aortitis is not uncommon in cattle. I have recently studied a tuberculosis of the aorta in a dog. A large nodule developed in the wall of the aorta near the heart, producing such weakening that a small bulging had resulted.

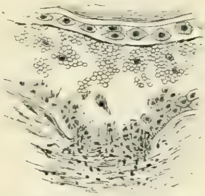

FIG. 633.—Perforation of the Elastic Layer by Caseous Intimal Focus, Infiltration into Media and Adventitia, and Beginning Aneurismal Bulging. Note beginning subendothelial proliferation in opposite wall from tuberculous leptomeningitis. (Hektoen, *The Journal of Experimental Medicine*, vol. i.)

The relation of tuberculosis of the blood-vessels to general miliary tuberculosis is discussed elsewhere. At this time it is sufficient to say that tuberculosis of the intima of blood-vessels or of the thoracic duct or tuberculous endocarditis constitutes an essential, intermediate stage in the development of acute general miliary tuberculosis. It is in the tuberculous areas that result from infection of the intima and of the endocardium that the germs multiply so freely that masses are thrown into the general circulation and produce on lodgment in the internal organs the numberless nodules characteristic of general miliary tuberculosis. There is no satisfactory evidence that tubercle bacilli multiply in the blood; hence miliary tuberculosis means the setting free into the circulation at one time of large numbers of bacilli (Weigert, Benda, Gaylord).

The vascular changes in tuberculous leptomeningitis are interesting and well marked. There is a tuberculous endarteritis characterized by the formation of intimal tubercles and a diffuse subendothelial intimal proliferation (Figs. 633 and 634), probably induced by the implantation of tubercle bacilli from the blood. From the intima the infiltration may spread into the muscular coat and the adventitia and the whole wall may undergo caseous and hyaline degeneration. Occasionally, though rarely, the intimal process so weakens the wall that small, local dilatations take place—a species of mycotic aneurism. Proliferation in the adventitia may invade the media and the intima and the whole wall of the arterial segment may undergo degeneration. In tuberculous leptomeningitis the muscularis often presents the hyaline degeneration described by Guarnieri and others. The epithelioid cells that constitute such a prominent feature of the intimal proliferation undoubtedly originate from the subepithelial connective tissue rather than from the epithelial lining, which appears to remain intact until caseation takes place. Plasma cells and phagocytic cells are also present.

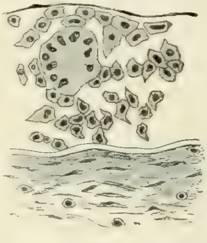

FIG. 634.—Subendothelial Intimal Proliferation with Multinuclear Giant Cell. From tuberculous leptomeningitis. (Hektoen, *The Journal of Experimental Medicine*, vol. i.)

In this form of tuberculosis adjacent extravascular and arterial foci frequently extend to the veins (Fig. 635).

Banti describes a case of general tuberculosis in which nearly the whole length of the superior vena cava was completely filled by a mass of neoplastic tuberculous tissue which projected into the right auricle.*

ACTINOMYCOSIS.—As actinomycosis spreads through the tissues by direct extension, no anatomical structure is absolutely secure from invasion, not even the blood-vessels. In metastatic actinomycosis the fungus gains entrance into the circulation by the direct involvement of the walls of the blood-vessels in the vicinity of a local process. In the cases in which the point of invasion of the vascular system has been directly demonstrated it concerns some of the larger veins and cerebral sinuses.

The meningeal sinuses and veins are frequently attacked in cranio-cerebral actinomycosis. In many cases of actinomycotic phlebitis the generalization of the process is undoubtedly prevented or delayed by consecutive thrombosis.

Ponfick describes an actinomycotic proliferation which projected button-like into the lumen of the internal jugular vein; this invasion became the direct or indirect source of secondary foci in the heart, lungs, spleen, and brain.

In a case of primary pulmonary actinomycosis with extension through the diaphragm and into the spleen, Arnold Paltauf found the splenic vein infiltrated and thrombosed, the thrombosis extending into the portal vein; there were metastatic foci in the liver and in the brain. Lüning and Hanau describe perforation in the hepatic vein in a secondary actinomycosis of the liver. In pulmonary actinomycosis with extension to the pleura and pericardium Habel found the base of the heart and the larger vessels surrounded by a spongy tissue; just above the entrance into the auricle the superior vena cava presented a circumscribed area in which the normal wall was substituted by a nodular mass of pale yellow color; the jugular veins were thrombotic. Abée describes an actinomycotic perforation of the inferior vena cava. Beginning in the œsophagus the process spread out in the prevertebral, mediastinal, and peripleural tissue, and invaded the diaphragm and the spinal column. The infiltration between the right lung and the diaphragm surrounded the inferior vena cava in the form of a layer, 3 to 4 cm. thick, of a reddish, soft tissue riddled with confluent abscesses. At the point where the vein enters the auricle its lumen was materially narrowed, the intima roughened, covered by parietal thrombi and perforated by numerous yellowish suppurative foci; below, the vein was partially filled with a large softened thrombus. There were numerous metastatic actinomycotic abscesses in various parts of the body.

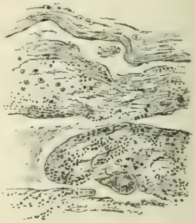

FIG. 635.—Focal Tuberculous Infiltration with Giant Cell, Extending through Wall of Vein with Secondary Thrombosis, Caused by Extension in Tuberculous Leptomeningitis. (Hektoen, *The Journal of Experimental Medicine*, vol. i.)

LEPROSY.—Leprous nodules sometimes occur in the walls of the veins in leprosy of the extremities

PERIARTERITIS NODOSA.—This remarkable disease was described by Kussmaul and Maier in 1866. Cases had been observed previously by Pelletan in 1810 and by Rokitansky, but their descriptions were confined to the macroscopic appearances. Since Kussmaul and Maier fastened the attention upon the disease additional instances have been recorded, so that the total number of cases now is thirteen (von Schrötter). All of the cases have occurred in Central and Southern Germany except one—a Russian instance (Freund). The disease appears to attack young persons mostly between twenty and thirty; it occurs also in children. The male sex has so far furnished more cases. The symptoms are, generally speaking, those of a more or less severe toxic polyneuritis and polymyositis with constitutional and digestive disturbances, abdominal pain, renal symptoms, etc. In nearly all cases a peculiar anæmia and general weakness have been recorded. The whole course of the disease takes from six to twelve weeks, the termination as far as known being always fatal. In Kussmaul and Maier's instance minute nodules were present in the skin of the face, neck, and upper extremity. It is quite likely that in the future the disease will be diagnosed during life, especially in instances with subcutaneous nodules which might be excised and examined microscopically. Clinical observation has not brought out any common or striking etiological conditions. Syphilis has been present in some cases and definitely excluded in others.

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* Mügge: Virchow's Archiv, Bd. 76.

The vascular lesions consist of nodular, eccentric, and more diffuse thickenings of arteries of the general size of the coronaries and hepatic and smaller; the swellings are grayish and grayish white in color, vary in size from pinhead to pea and larger, occur especially at the branchings, but also in the course of the arteries both when free and intraparenchymatous. The distribution and number of the swellings, usually present in great numbers, vary somewhat in different cases (Weichselbaum and Thompson); the favorite locations are the mesenteric (including the intraparietal branches of the gastro-intestinal tract), and the coronary, then the muscular, intraneural, renal, hepatic, splenic, bronchial, and subcutaneous. Nodules have also been described at the origins of the intercostal branches of the aorta and of branches of the crural and popliteal arteries. It is noteworthy that up to this time the veins have not been involved (Fig. 636).

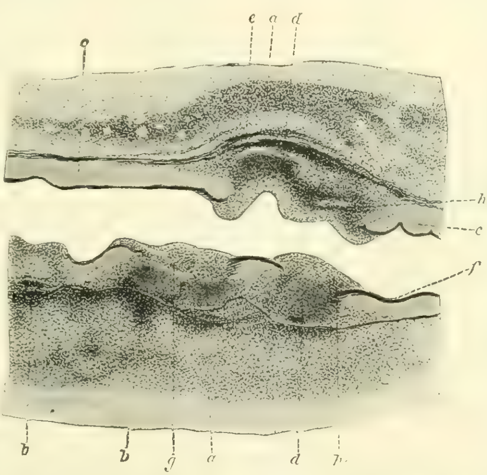

Fig. 636. Periarteritis Nodosa. Longitudinal section of a small muscular branch. (After Freund.) *a*, Adventitia, greatly infiltrated with cells; *b*, foci of especially dense cell accumulations in adventitia; *c*, normal media; *d*, degenerated media; *e*, external elastic lamina, bulging outward; *f*, internal elastic layer; *g*, remnants of internal elastic layer; *h*, proliferating intima.

The histogenesis of the arterial lesions, which are of an inflammatory nature associated at times with aneurismal dilatations, fibrous tissue formation and thrombosis, is not agreed upon. Fletcher, von Kahlden, and Freund regard the process as primarily inflammatory, due to the action of some unknown substance, which reaches the adventitia by way of the vasa vasorum. This view is supported by the presence, in Fletcher's case, of nodules upon the vasa vasorum and by the microscopic appearances in the early stages of the process (Freund). Accordingly, the inflammatory round-cell infiltration, which appears to be of a non-specific type, begins in the adventitia and extends through the media to the intima, producing in the last marked cellular accumulations between it and the media. As a result of the inflammation the muscular coat undergoes a circumscribed hyaline degeneration, and hyaline material, probably of exudative origin, also appears in the subepithelial layers. There are not many polymorphonuclear cells in the cellular infiltration, which consists largely of spindle-shaped cells with large nuclei. Freund did not find proliferation in the intima when the media was normal. Eventually the internal elastic coat and the media are so thinned and destroyed that circumscribed aneurismal bulgings of the vessel wall may occur, but the formation of aneurisms is not constant because the development of fibrous tissue may prevent dilatation.

Others, like Weichselbaum and Chvostek, hold that the process is primarily an endarteritis, which extends to the outer coats. In the case of smaller arteries and of vasa vasorum this would seem to be the fact probably.

It has been suggested that periarteritis nodosa is a primarily multiple tumor of the nature of lymphoma, beginning in the adventitia. Circumscribed accumulations of cells occur in the adventitia that resemble lymphomata; but the singular fact that the process is confined to arteries speaks against this view. The subsequent formation of fibrous tissue is also inconsistent with this theory.

Meyer regarded tears in the media as the essential cause, and Eppinger has elaborated the theory that periarteritis nodosa is the result of the formation of multiple aneurisms on account of ruptures of the elastic elements, which are congenitally weak and imperfect. Eppinger proposes to call the disease congenital aneurism. The proliferation observed, in the adventitia and intima, which constitutes such a striking feature of the lesions, is regarded by Eppinger and the supporters of the aneurismal theory (von Schrötter) as secondary; and the thrombi and hard fibrous masses sometimes observed are similarly explained. Aneurisms are not observed in every instance of periarteritis nodosa; in Pelletan's, Rokitansky's, Eppinger's, Weichselbaum's, and Meyer's cases they were marked. In Pelletan's case sixty-three aneurisms were present. The development of aneurisms is consistently explained on the score of more marked inflammatory and degenerative weakening of the arterial wall in some nodules than in others in which these processes were not so rapid. Any evidence of a histological nature of a congenital structural imperfection of the arteries in periarteritis nodosa has not been furnished. Eppinger's theory does not satisfactorily explain the relative infrequency of involvement of the cerebral arteries, which would seem to be as liable to aneurismal dilatations as other arteries, if not more so. The clinical course of the disease is also against this view.

The histological appearances and the genesis of the changes as explained by Freund and others rather favor the view that periarteritis nodosa is a primarily inflammatory process in the further course of which aneurisms frequently develop; but further studies are essential before the question of the nature of this disease can be definitely established. Micro-organisms have not been found in the lesions. Syphilis has been suggested as the underlying condition. Graf finds histologically periarteritis nodosa resembles not a little Heubner's endarteritis syphilitica; and the appearances described by Abramow in two cases of syphilitic arteritis involving many of the smaller arteries, except the cerebral, are also decidedly suggestive of periarteritis nodosa, the clinical symptoms of which were absent, however. The absence, in some cases of periarteritis nodosa, of all history of syphilis and the freedom of other organs from syphilitic lesions and their consequences are also against the specific theory; and it does not appear that the vascular lesions of periarteritis nodosa ever present nodular foci of cell accumulations with central necrosis such as occur in the gummous form of syphilitic arteritis. Periarteritis nodosa must be regarded, for the present, as a distinct disease, histologically and clinically. Syphilitic periarteritis should not be included under periarteritis nodosa, as is done by some writers like Mott in Allbutt's "System."

Many of the clinical symptoms are evidently due to secondary lesions in the internal organs. Although the intramyocardial branches of the coronary arteries are generally involved, the myocardium itself usually presents but slight changes. Whether bronchitis and other inflammatory changes in the lungs are directly secondary to changes in the bronchial arteries, the pulmonary being usually free (von Schrötter), cannot be stated. The mucous membrane of the gastro-intestinal tract has been found to be the seat of multiple ulcers and hemorrhages; the ulcers in the stomach being more of the nature of erosions while those in the intestines may resemble typhoid ulcers. These changes are regarded as the result of circulatory disturbances in the areas nourished by the affected branches, many of which become entirely occluded by thrombosis. Enlargement of the mesenteric glands is usually present. The spleen may be the seat of infarcts, in various stages of absorption, caused again by the occlusion of terminal arteries. Pressure of the nodules in the intrahepatic branches of the hepatic artery on the bile ducts may cause jaundice (von Schrötter). Severe changes are produced in the kidneys. Multiple ischæmic necrosis results from thrombosis of the affected arteries. Degeneration of the glomeruli, hemorrhages, parenchymatous and interstitial changes develop, due either to extension of the vascular changes or to the action of toxic substances in the blood. The changes in the peripheral nerves and in the skeletal muscles explain well the nervous and muscular phenomena observed clinically. The pressure of changed arteries upon adjacent nerves may cause degenerations, and in Freund's case foci of degeneration in the nerves were found to correspond to nodules upon intraneural arterial branches. The development of nodules upon the intramuscular arteries gives rise to granular and fatty disintegration of the muscle fibres and to waxy changes.

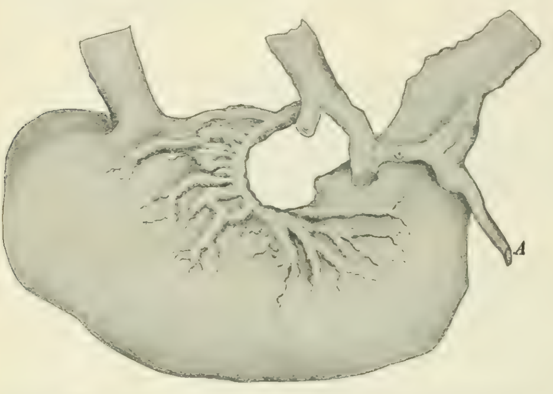

FIG. 637. Growth of Carcinoma into the Gastric and Portal Veins and the Radicles of the Latter, Secondary to Carcinoma of the Pylorus. The posterior surface of the stomach, which is turned so that the pylorus is to the left, is exposed. *A*, Cut end of gastro-duodenal vein.

In Weichselbaum's case the rupture of an aneurism, 2 cm. in diameter (the largest so far recorded in periarteritis nodosa), upon the arteria profunda cerebri gave rise to hemorrhage.

TUMORS.—The primary tumors composed of blood-vessels—the various forms of angioma—are described in the article on *Tumors*. Here is described also the part that blood-vessels play in the general dissemination of the malignant tumors. Primary tumors rarely develop in the walls of blood-vessels. Brodowski has described a primary sarcoma of the thoracic aorta, which started in the adventitia and extended through the muscular coat and into the intima; the sarcomatous infiltration of the intima produced a marked thickening of the latter.

I have described an interesting pedunculated outgrowth of the intima of the basilar artery, which at that time was regarded as a fibroma. It is possible, however, that the outgrowth in reality was the result of an endarteritic proliferation of inflammatory nature.

Several instances of myoma, fibroma, and sarcoma have been described as primary in veins (Orth).

Secondary tumors occasionally occur in the walls of the blood-vessels. Quincke, in "Ziemssen's Encyclopedia," cites an instance, described by Broca, of cancer at the root of the aorta with rupture into the pericardium. Friedrich describes metastatic nodules of a papillary cystocarcinoma of the ovary in the wall of the thoracic and abdominal aorta and the renal artery; here the metastases evidently occurred through the vasa vasorum. The nodule in the thoracic aorta ruptured into the lumen of the vessel.

Extensive intravascular growth of malignant tumors, especially in the veins, takes place in the case of sarcoma of various kinds, especially of the bones, in adrenal tumors of the kidneys, etc. Intravascular growth of this kind has extended from the renal vein, for instance, to the heart.

In carcinoma of the stomach I have observed an extensive intravenous growth of the tumor resulting in a kind of carcinomatous injection of all the veins about the lesser curvature of the stomach and of the portal vein (Fig. 637). Orth observed the entire venous plexus of the dorsum of the foot filled with sarcomatous masses.

Norïca and Haret* describe a carcinoma of the stomach with metastases in the mesenteric, mediastinal, and deep cervical glands, followed by carcinomatous invasion and thrombosis of the superior vena cava, the two brachiocephalic, subclavian, and internal jugular veins. In 1885 Oulmont collected nineteen cases of obliteration of the superior vena cava. He distinguished two groups, namely, obliteration by pressure and obliteration by concretion. The first group comprised five cases due to cancer of the mediastinum or of the lung, two cases due to tuberculous lymph glands, and four cases due to aortic aneurism. The second group included five cases of thrombosis and three cases of cancerous invasion. Comby and Rendu each report a clinical case in which aneurism of the aorta was thought to be the cause. I have examined post mortem a case of this kind, in which an aneurism of the ascending aorta compressed the superior vena cava, which was wholly obliterated by the formation of fibrous tissue in the intima. The occlusion took place gradually and resulted in a great dilatation of the subcutaneous thoracic and abdominal veins which for years furnished routes for collateral circulation. Letulle lays stress on occlusion of the large veins of the neck and mediastinum on account of propagation of carcinomata of the glands, the thyroid, and the thymus.

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* Bulletins et mémoires de la Société Anatomique de Paris, 1899, lxxiv., 861.

Gallavardin reports thrombosis of the large cervical veins in mitral stenosis. The extensive occlusion described by Norïca and Haret has been equalled by the case of Reid only, which is included in Oulmont's series. There was in Norïca and Haret's case dilatation of subcutaneous veins of the right side of the chest and abdomen, showing that the blood in the superior vena cava was diverted into the inferior by way of the azygos vein. This diversion furnished a sufficient collateral circulation. The condition of the thoracic duct was not examined.

Ludvig Hektoen.

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BLOUNT SPRINGS.—Blount County, Alabama.

POST-OFFICE.—Blount Springs. Hotel.

ACCESS.—Viâ Alabama and Chattanooga Railroad, also viâ Louisville and Nashville Railroad to Elyton.

The springs are about thirty miles northwest from this station. The waters of Blount Springs may be classed as saline sulphureted. The springs are six in number, and are located in a triangular valley 1,580 feet above the sea level.

ONE UNITED STATES GALLON CONTAINS:

Solids.	No. 1 Red Spring. R. T. Brumby.	Sweet Spring. Brumby.	Spring No. 4. Summers.
	Grains.	Grains.	Grains.
Magnesium carbonate	4.40	3.60	9.40
Calcium carbonate	6.80	4.48	5.72
Barium carbonate	....	....	.91
Iron carbonate	1.92	1.12	3.19
Sodium carbonate	....	....	....
Magnesium sulphate	1.60	2.40	....
Calcium sulphate	....	....	1.27
Calcium phosphate	....	....	Trace.
Potassium chloride	....	....	7.07
Sodium chloride	32.32	30.88	23.21
Magnesium chloride	6.00	....	2.04
Iodides	....	....	....
Magnesium iodide	....	....	.14
Magnesium bromide	....	....	.16
Lithium	....	....	Trace.
Alumina	....	....	Trace.
Silica	....	....	2.44
Sulphur	....	....	...
Total	53.04	42.48	55.55
Gases.	Cu. in.	Cu. in.	Cu. in.
Carbonic acid	6.00	6.00	4.72
Sulphureted hydrogen	14.96	12.56	30.67
Oxygen	....	....	7.08
Nitrogen	...	....	

J. K. Crook.

BLUE HILL MINERAL SPRING.—Hancock County, Maine.

POST-OFFICE.—Blue Hill. Hotels.

ACCESS.—Viâ steamer from Portland, also by stage from Ellsworth, fourteen miles distant.

The Blue Hill Mineral Spring is located two and one-half miles northwest of Blue Hill village, and about six hundred feet in perpendicular height above the base of Blue Hill Mountain. Its situation assures freedom from all surface impurities. The existence of the spring was noticed by Dr. Charles T. Jackson in his second report of the geology of the State of Maine, published in 1838. It was not until recently, however, that improvements were made. A handsome and commodious building has been erected for the comfort of tourists and visitors at the springs, and a large bottling plant established. An analysis by Prof. S. P. Sharples, of Boston, resulted as follows:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	0.29
Sodium sulphate	.81
Sodium carbonate	.15
Calcium carbonate	1.87
Iron carbonate	.59
Silica	1.07
Organic matter	Traces.
Total	4.78

This is an excellent table water, and it also possesses mild diuretic and tonic properties. It is used commercially. *J. K. Crook.*

BLUE LICK SPRINGS.—Saline County, Missouri.

Post-Office.—Marshall. Cottages at spring.

Access.—Viâ Chicago and Alton, or Jefferson City, Boonville and Lexington branch of the Missouri Pacific Railroad to Marshall, thence eight miles by stage south to springs.

Saline County, Missouri, is entitled to eminent distinction as a water-producing district. Thousands of clear, pure-water springs of more or less volume are well distributed over its surface. They are found in large numbers along the Missouri, Blackwater, and Salt River bluffs, and at the base of the minor hills in all parts of the county, and are unfailing at all periods of the year. The most remarkable natural resources of the county, however, are its mineral waters, which for volume, variety, and medicinal value are among the finest in the country. Not less than two thousand mineral springs, some of them of immense flow, are found in the limits of the county. Some of these springs will, no doubt, take a prominent place among the health resorts of the country when they shall have been properly developed. At the Blue Lick Springs are more than thirty distinct fountains in a pretty valley at the base of picturesque wooded bluffs, all within a radius of thirty feet. The largest of the group, known as the "Gum" Spring, is an immense salt fountain of 57° F., which was formerly the site of extensive salt works, but is now the centre of a large bathing establishment. Nearby is the "Blue Lick" Spring, the most important of the group. Then there are numerous black sulphur, magnesian, chalybeate, and sweet springs, besides uncounted saline springs. Many of these have been analyzed by State Chemist Paul Schweitzer, who found in them the following mineral ingredients:

Sodium chloride.
Potassium chloride.
Calcium chloride.
Magnesium chloride.
Lithium chloride.
Calcium carbonate.
Iron carbonate.
Magnesium carbonate.
Manganese carbonate.
Magnesium bromide.
Magnesium iodide.
Magnesium sulphate.
Potassium sulphate.
Calcium sulphate.
Barium sulphate.
Calcium sulphite.
Sodium sulphite.
Ammonium nitrate.
Magnesium nitrate.
Calcium phosphate
Alumina.
Silica
Sulphur.
Carbonic acid gas, large quantities.
Sulphureted hydrogen gas, large quantities.

Many of these ingredients serve to endow the waters with valuable remedial qualities. A complete qualitative analysis of the Blue Lick Spring, for which the collection is named, resulted as follows:

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	57.84
Magnesium sulphate	26.13
Magnesium chloride	10.94
Sodium chloride	493.88
Potassium chloride	.64
Silica	8.16
Alumina	10.23
Organic matter	2.48
Total	610.30
Gases.	**Cu. in.**
Free carbonic acid	53.22
Sulphureted hydrogen	Not estimated

It will be seen that the waters are very similar to those of the Blue Lick Springs of Kentucky, for which these springs are named.

The water is well adapted for the treatment of constipation, especially when due to engorgement of the portal system. On the other hand, it is also said to act beneficially in many cases of chronic diarrhœa. It acts with advantage in many of the conditions due to a sluggish liver, such as hemorrhoids, jaundice, etc. Being a very efficient diuretic, the water is useful in certain renal and bladder disorders. Within sixty steps of the Blue Lick Spring are three black sulphur springs; two hundred and fifty yards south is the Sweet Spring, which has been found to be a very efficient diaphoretic and diuretic. It is entirely free from sulphur and forms a very pleasant beverage. *James K. Crook.*

BLUE RIDGE SPRINGS.—Botetourt County, Virginia.

Post-Office.—Blue Ridge Springs. Hotel and cottages.

Access.—Viâ Norfolk and Western Railroad. The hotel is located near the railroad station.

This resort has a picturesque location in the midst of the Blue Ridge Mountains, the elevation being about thirteen hundred feet above the sea level. The springs yield about one hundred and twenty gallons of water per hour, having a temperature of 52° F. the year round. The water has been analyzed by Prof. Henry Froehling, with the following results:

One United States Gallon Contains:

Solids.	Grains.
Magnesium sulphate	47.01
Calcium sulphate	100.13
Sodium sulphate	.37
Potassium sulphate	.65
Magnesium carbonate	1.61
Calcium carbonate	3.96
Strontium carbonate	.29
Barium carbonate	.02
Manganese carbonate	.02
Nickel and cobalt carbonate	Trace.
Iron (ferrous) carbonate	.11
Lead carbonate	Trace.
Copper carbonate	Trace.
Sodium chloride	1.26
Lithium chloride	.04
Sodium arseniate	Trace.
Sodium iodide	Trace.
Sodium bromide	Trace.
Calcium fluoride	Trace.
Magnesium nitrate	.35
Ammonium nitrate	.03
Aluminum phosphate	.02
Aluminum silicate	.15
Silicic acid	1.35
Total	157.37
Carbonic acid combined	2.57
Gases.	**Cu. in.**
Carbonic acid (free)	38.20
Sulphureted hydrogen	3.00

The water is used commercially. It is pleasant to drink and bears transportation well. It is useful in dyspepsia, especially when attended by acidity, and it seems to act as a corrigent or regulator of secretion, being efficacious both in diarrhœa and in constipation. The water also possesses excellent tonic properties. *J. K. Crook.*

BOCCONIA.—A powerfully medicinal and poisonous genus of plants in the *Papaveraceæ* or Poppy family. "*B. cordata* Willd.," more properly *Maclaya cordata* (Willd.) R. Br., of China and Japan, is a stout perennial herb, largely cultivated as an ornamental plant, the roots of which are used medicinally. It contains at least three alkaloids (*vide* Schlotterbeck), namely, protopine in large amount, β-homochelidonine, and chelerythrine, and possibly sanguinarine also. *B. arborea* Watson, of Mexico, and *B. frutescens* L. and *B. integrifolia* Kunth. of tropical America, are small trees or large shrubs, the bark of which is used similarly. These barks are rich in alkaloids and resinous matter. The alkaloids have been isolated and somewhat studied in the Instituto Medico Nacional of Mexico, and names assigned them; but apparently insufficient care was taken in comparing them with known alkaloids of other members of the family, notably of sanguinaria. If they are not absolutely identical with the latter, they are at least very similar in physiological action, as well as chemically. These drugs have been very little studied in any way, but richly deserve it. The writer has found the leaves of *B. frutescens* highly prized among the Indians of South America, but their uses there give little clue to their special properties. *H. H. Rusby.*

BOERNE, Texas, is a town of 800 inhabitants situated in the southwestern part of the State, 30 miles northwest from the city of San Antonio. Its altitude is about 1,670 feet, which gives it somewhat the characteristics of a mountain resort of moderate elevation. The soil is composed of gravel and sand with occasional streaks of adobe, and a substratum of porous limestone. The drainage is good, both on account of the slope and on account of the porous character of the soil.

Dr. I. M. Cline, quoted in Solly's "Medical Climatology," 1897, who has charge of the Texas weather service, describes the country in which Boerne lies as follows:

"Between latitude 29° 45′ and 30° and to the 100th meridian on the west, the elevation changes rapidly from one thousand to two thousand feet, with considerable irregularity, and is broken with deep ravines and small creeks, and along the western border, as the two-thousand-foot line of elevation is reached, it is much sculptured by erosion. The soil between these elevations is very irregular in its formation, but is to a great extent of the black, stiff soil over the eastern portion, and then blends toward the west with black and red sand and red loam, with a pebbly soil in some parts; it is also crossed here and there by strips of white, sandy land, with a growth of scrub post-oak."

The monthly mean temperature for eight years, arranged by seasons, is given by Solly as follows: Winter, 50°; spring, 69°; summer, 79°; autumn, 65°. Mean for January, 49°; for July, 81°; for the year, 65°. The total seasonal rainfall, based on nine years' records, is given by the same authority as follows: Winter, 5.9 inches; spring, 9.6 inches; summer, 6.4 inches; autumn, 4.9 inches. Annual mean, 27 inches. The mean relative humidity is from 66 to 72 per cent. Occasionally during the winter months there is a sudden fall in temperature during the prevalence of a "norther"; this fall depends on the velocity of the wind and ranges from 5° to 25° F., and lasts from a few hours to three or four days. The windfall is light, the prevailing winds blowing from the south and southeast, the velocity ranging from four to seven miles an hour, and occasionally increasing to from fourteen to twenty-five miles during a "norther." "From the fact," says Miller ("Boerne and Adjacent Country," by Dr. William Miller, Resident Physician), "that the wind passes over miles of land covered with grass and trees before reaching Boerne, it is not accompanied with clouds of dust or sand," which, as Dr. Miller adds, is a very important matter with persons suffering from diseases of the respiratory organs.

There are a few light morning fogs in the late autumn and winter, not exceeding a total of eight days in the year. The average number of sunny days is 277, and of cloudy 88. The number of days in which there is more or less sunshine, and in which an invalid can be out of doors, is 355. In Boerne and the adjacent country there are no prevailing diseases of a contagious or epidemic nature. The whole of this elevated district is above the yellow-fever line (Miller).

The water supply is chiefly obtained from wells of an average depth of thirty-five feet, and the water is considered fairly good for drinking purposes. Cistern water is also used. About three miles from Boerne are the Indian Mineral Springs, so named from the fact that they were visited periodically by various Indian tribes, who came bringing their sick with them. This water is also used as a table water. The analysis made by C. F. Chandler, Ph.D., of New York, is as follows:

In One United States Gallon There Is:

Solids.	Grains.
Chlorine in chlorides	0.512
Equivalent to sodium chloride	.844
Oxides of iron and aluminum	.093
Lime	45.832
Magnesia	6.435
Sulphuric acid (SO_3) in sulphates	67.246
Silica	.355
Solids of evaporation	138.388

There are several fairly good hotels and boarding houses in the town or near by. Boarders are also received in the ranch houses in the neighborhood. The attractions are riding, driving, hunting, and fishing, and there are various pleasant excursions in the vicinity. The class of diseases which this climate is likely to benefit are pulmonary tuberculosis, chronic rheumatism, renal, nervous, and malarial diseases.

When one considers the low relative humidity, the equable climate, and especially the very large number of sunny days in the year (277), the inference is warranted that Boerne is admirably fitted for the open-air treatment of pulmonary tuberculosis. While experience has verified this conclusion, the fact still remains that here, as in so many other climatically excellent health resorts in this country, there is lacking the certainty of finding such hygienic conditions as the consumptive requires. Climate is only one of the factors in the cure of phthisis, and it will often prove an illusory one unless those other factors are also present, viz., careful medical supervision and opportunities for obtaining proper food, well-ventilated sleeping apartments, and means for the rest cure.

Edward O. Otis.

BOIL.—(Synonyms: French, *Furoncle, Clou*; German, *Blutschwar; Furunkel.*)

Definition.—A boil or furuncle is the result of an acute phlegmonous inflammation of the skin and underlying connective tissue surrounding a skin gland or follicle, which is followed by suppuration and the extrusion of a central slough or core.

Symptoms.—A boil begins with a certain amount of infiltration around a skin gland or follicle, which soon manifests itself as a small, somewhat itchy, and slightly painful pimple. Very soon the lesion assumes a conical shape, becomes more tender, and is surrounded by a zone of reddened skin. The boil increases in size with considerable rapidity until about the third or fourth day, when it reaches its full development. The pain likewise grows in intensity, becoming a dull ache, and there is much throbbing and sensation of tension. All of these symptoms are intensified at night. The area of the furuncle varies considerably, depending upon the density of the skin in the affected part, and the consequent facility with which the infiltration may spread. Finally, at the apex of the boil a point of suppuration appears, and in a week or ten days the lesion matures or becomes "ripe." If pressure is made over a boil before it is quite mature a little pus or bloody serum may be made to exude; but later, either spontaneously or as the result of surgical interference, the core escapes, although not always very readily. The expulsion of the core exposes to view a small cavity which quickly heals, to be followed in turn by a purplish discoloration and ultimately by a minute scar. Lymphangitis and swelling of the lymphatic glands frequently occur in connection with boils, and sometimes constitutional symptoms are marked. When a core does not form, as occasionally happens, it is called a blind boil. Boils may occur singly or in groups; often they come out in successive crops, and keep on appearing for long periods, constituting the condition known as furunculosis. The so-called "furuncular diathesis," especially as seen in children, may produce great restlessness, sleeplessness, anorexia, and emaciation due to pain and the free discharge of pus. It may be of interest in this connection to mention that under the name of "hidradenitis suppurativa" Pollitzer * has called attention to a suppurative inflammation of the sweat glands which results in their destruction and the production of scars. It is the same condition originally described by Verneuil.

Situation.—While boils may develop anywhere on the general surface, except the palms and soles, they show a marked predilection for the back of the trunk and neck. They also occur in the armpits and at the borders of the lids (styes) and in the external auditory canal, in which latter situation they excite great pain.

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* Jour. Cutan. and Genito-Urin. Dis., January, 1892.

Pathology and Etiology.—It is now conceded that boils are due to the entrance of pus cocci (staphylococcus aureus or albus) into the openings of skin glands or hair follicles. According to the researches of Bockhardt,* if the micro-organisms do not penetrate into the cutis, simple impetigo results; if they pass vaguely into the cutis through some lesion in the epidermis, a skin abscess will occur; but if they pass along the duct of a sweat gland or penetrate the lumen of a hair follicle, the process of suppuration is more acute and a furuncle results, the suppurating gland or duct representing the core. Direct inoculation or experimental cultures show conclusively the contagious nature of boils, as was pointed out long ago by Startin. According to Melsome,† it is not possible to obtain cultures in the œdematous area surrounding a boil; however, when a furuncle is large, or is rapidly followed by others in its immediate vicinity, the pus cocci pass through the abscess walls and travel along the lymphatics, producing swelling of the lymph glands, and in severe cases they may even gain access to the general circulation and induce septicæmia.

It is said that women are less subject to boils than men, and that while boils are not uncommon in infants, they are most frequent in boys and young men. Solitary boils are often found to be due to some local irritation, *e.g.*, chafing of rough or frayed garments, decubitus, etc., the irritated skin more readily allowing the penetration of pus organisms. A condition of furunculosis of the back of the neck is not infrequent as the result of infection from the fingers of barbers and the use of the dirty implements of their trade.

Sweaters and other garments worn by young men in training and in athletic games frequently become infected and give rise to boils in otherwise singularly healthy persons.

It is a matter of common experience that furuncles complicate many disorders of a depressing character, *e.g.*, diabetes, variola, typhoid fever, etc. Severe pruritic diseases are also often complicated or followed by boils; for example, eczema in children. In the hot summers experienced in this country the very frequent prickly heat is frequently followed by boils, both in children and adults.

The condition known as furunculosis, or recurrence of boils in crops, is due to local reinoculation and not to the state of the blood, although it is undoubtedly true that the nutrition of the soil will have much to do with the pathogenetic action of the pus cocci.

With our present knowledge of the pathology of boils it may be readily understood how boils sometimes occur quasi-epidemically in families and schools.

Diagnosis.—A boil is to be distinguished from a carbuncle by its conical shape and its single suppurating point; a carbuncle, on the other hand, is larger and flatter than a boil, has several openings, and is surrounded by a much more brawny induration. The difference really is one of degree, the carbuncle being, however, clinically, a much more formidable affection.

Treatment.—In all cases, especially when the eruption has existed for a long time, it is advisable, in addition to the local measures presently to be described, to look into the hygienic surroundings and general health of the patient. The urine should be examined for albumin and sugar, and if these are discovered the proper treatment for those conditions should at once be adopted. All local sources of irritation and possible infection should be diligently sought and removed. Old smoking jackets, sweaters, etc., should be regarded with suspicion. A proper disinfection of barber's tools should be insisted upon.

Now that the specific character of the furuncle is better understood there is less insistence upon the administration of the host of remedies that are supposed to be "good for boils."

Among such remedies may be mentioned yeast in doses of a half-wineglassful morning and night, and the sulphide of calcium so highly praised by Ringer. It is quite possible that the sulphide of calcium may possess some germicidal properties, but it must be given in much larger doses than those usually recommended. Dilute sulphuric acid in ten to twenty drop doses, well diluted, every three or four hours, is highly esteemed by some physicians. Medicines that improve the general nutrition, thus rendering the individual less susceptible to local infection, are of undoubted value in furunculosis; for example, iron, arsenic, cod-liver oil, the hypophosphites, and the syrup of the lacto-phosphate of lime may be prescribed with hope of benefit in suitable cases.

As regards the direct treatment of the boil itself an effort should be made to prevent if possible, or at least limit, the suppuration. Very often a boil may be aborted by the application of a salicylic acid plaster, as after L. Heitzmann's formula:

℞ Acidi salicylici	ʒ ij.
Emplastri saponis	℥ ij.
Emplastri diachyli	℥ i.

M. S. Spread on cloth.

Other remedies of this class are iodine, boric acid in saturated solution, and ichthyol. Halle and Jamieson advise the following application:

℞

Tincturæ iodi	ʒ i.
Acidi tannici	ʒ ss.
Pulveris acaciæ	ʒ ss.

A few drops of carbolic acid injected into the apex of a boil will often cause it to abort. An electrolytic needle will do the same thing. If a hair occupies the centre of a furuncle it is best to extract it.

Unna's mercuric-carbolic plaster often succeeds in aborting a boil; but if suppuration has already begun, nothing succeeds so well in hastening it. A hole should be cut in the centre of the plaster corresponding to the apex of the boil. When boils are very painful the common practice is to apply a hot flaxseed poultice, but unless it is rendered antiseptic by the addition of carbolic acid it is apt to prove mischievous by favoring reinfection in the vicinity. The following ointment serves all the purposes of a poultice, does not encourage reinfection, and allays pain most decidedly:

℞ Pulveris iodoformi	ʒ i.
Unguenti vaselini plumbici	℥ i.

M. S. Spread on patent lint.

If the patient exhibits any idiosyncrasy in regard to iodoform, aristol or xeroform may be used in its place.

The internal administration of appropriate doses of phenacetine will usually secure sleep at night. If incisions are imperatively demanded the parts may be rendered insensible by a spray of ethyl chloride. It is an absolute necessity, especially where boils are multiple, to smear the intervening and surrounding skin with a paste made of equal parts of oxide of zinc and vaseline and four-per-cent. boric acid. Washing the skin with green soap and warm water and mopping on a solution of bichloride of mercury 1 to 1,000 often puts a stop to reinoculation. Clean underclothes should be put on frequently and the patient warned against carrying infection to other parts with his fingers. Squeezing and other manipulation of a boil should be avoided. After the boil has burst the resulting cavity should be treated on ordinary surgical principles. *W. A. Hardaway.*

BOLDO.—The leaves of *Peumus Boldus* Molino (fam. *Monimiaceæ*). This is a large, much-branched shrub or small tree of Chile, evergreen and highly aromatic, the leaves opposite, the flowers small, white, panicled, diœcious. The leaves usually dry of a brownish color. They are coriaceous and very thick, ovate or oval-ovate, blunt or emarginate, entire, rough, papillose and stellate-hairy. They contain numerous large oil vesicles, and have a strong, somewhat turpentine-like odor and an aromatic, burning taste.

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* Monatshefte für Derm., No. 10, 1887.
† Allbutt's System of Medicine, vol. i., 1896.

Boldo contains about two per cent. of a powerful volatile oil, with resin, a little tannin, three per cent. of the glucoside boldin, and one-tenth per cent. of the alkaloid boldine. The statements concerning the properties of the constituents are very discordant. According to Merck, the hepatic properties reside in the glucoside, the dose of which is 0.065 to 0.2 gm. (gr. i. to iij.), and the hypnotic properties in the alkaloid, the dose of which is 0.002 to 0.0065 gm. (gr. $\frac{1}{30}$ to $\frac{1}{10}$).

The properties of the leaves are very marked, and it seems strange that the drug should not have acquired a higher repute. Its original use was that of an alterative, with special reference to the liver. Marked sedative properties were encountered, and it has been considerably used as a hypnotic in insomnia. For the latter purpose the dose should be 2 to 4 gm. (ʒ ss. to i.), for the former a fourth as much. The drug should be systematically investigated. It is now very little used.

H. H. Rusby.

BONDUC.—*Bonduc Nut; Nicker Tree.*

The seeds of *Cæsalpinia Bonducella* (L.) Roxb. and of *C. Bonduc* Roxb. (fam. *Leguminosæ*).

These plants are not only abundant in India, where they are native, but have been very largely introduced to most tropical countries. The seeds have the shape of a smooth pea, but are one-half or three-fourths inch in diameter, and smooth and shining. Those of the *C. Bonducella* are of a peculiar gray lead-color, those of *C. Bonduc* yellowish brown. The former especially are classical in the medical history of India, the uses being numerous and varied, and some of them doubtless ignorant. Its chief reputation appears to have been in the treatment of malaria, and careful trial has shown it to possess antiperiodic properties of some importance. The seeds contain twenty-five per cent. of fixed oil, which has been expressed and used like other fixed oils. They also contain about two per cent. of an amaroid, which is a white powder, and apparently the active constituent. Like all seeds of their class, they are rich in protein. The shell contains tannin. The antiperiodic dose of the bitter principle is 0.1 to 0.2 gm. (gr. iss. to iij.).

H. H. Rusby.

BONE. (HISTOLOGY.)—Bone tissue is closely allied in genesis and in many of its structural features to the other members of the connective-tissue group, the most evident difference between it and other tissues of the same class consisting in the solidity and firmness of the basement substance. For in this, as in other connective tissues, we have to consider the cells and the basement substance and the way in which they are arranged to form the different varieties of tissue. The solidity of the basement substance of bone depends largely upon the deposition within it of calcium phosphate and carbonate, with small amounts of calcium fluoride, sodium chloride, and salts of magnesium. These inorganic salts, which form about two-thirds of the weight of the bone, are deposited in an organic matrix in such a condition of minuteness that they are not recognizable as particles even with high powers of the microscope. They may be dissolved out of the bone with dilute acids, leaving a translucent flexible material behind, which preserves the shape and general structural features of the bone.

The soft matrix which is left, after the extraction of its inorganic salts, may be converted into gelatin by boiling in water. It is sometimes called the cartilage of bone, or ossein; but there is no sufficient reason for using these names, since the matrix is really, both in chemical nature and in minute structure, closely allied to the basement substance of fibrillar connective tissue.

The varied gross appearances which different bones or different parts of the same bone present have given rise to the names *compact bone tissue* and *cancellous bone tissue* or *spongy bone.* But the essential structure of the tissue is the same in both, the difference consisting largely in the arrangement of the bone tissue proper, and its abundance in proportion to the marrow spaces or vascular canals which it encloses. The compact bone tissue is in general found in the outer portions of the bones, while the cancellous tissue is situated internally, either entirely filling the central portions or bordering the marrow cavities.

Bones are surrounded by a layer of vascular connective tissue called the *periosteum,* and contain, either in large central cavities or in the smaller spaces with which they are everywhere permeated, a delicate vascular tissue called *marrow.* We have, then, to consider: 1. bone tissue proper; 2. the periosteum; 3. the marrow.

1. *Bone Tissue Proper.*—If we remove the inorganic salts from one of the long bones, by soaking it in dilute chromic or picric acid (see article on *Histological Technique*), and then make a thin longitudinal section, microscopical examination with a low power of these sections, stained with eosin and mounted in glycerin, reveals a picture like that represented in Fig. 638. The more solid portions of the bone show a series of narrow canals, running in a direction in general parallel with the long axis of the bone, and in frequent communication with one another by similar short transverse or oblique canals. These are the so-called *Haversian canals,* and contain blood-vessels, and, depending upon their size, few or many variously shaped cells. Along these Haversian canals the basement substance will be seen arranged in a series of lamellæ, while in and between these lamellæ lie small, elongated cavities called lacunæ, in which are the bone cells. Transverse sections, however, through the middle of a long bone, reveal with more distinctness the arrangement of the lamellæ of the basement substance (Fig. 639). The Haversian canals, which are cut transversely or obliquely across, are surrounded by a series of concentric lamellæ. These Haversian lamellæ, with their enclosed lacunæ, together with the canals and their contents, form the so-called *Haversian systems.* Filling the larger and smaller irregular areas between the Haversian systems are other parallel lamellæ, which run in various directions, and which are called *intermediary systems.* Beneath the periosteum, at the external surface of the bone, is a thinner or thicker system of lamellæ called *circumferential* or *general lamellæ,* which cover over large numbers of the Haversian systems and surround the entire bone. Sometimes similar but less well-defined general systems of lamellæ border the marrow cavity, but more often the internal surface of the compact bone is beset with a series of projecting bony trabeculæ, consisting of lamellæ similar to those forming the systems of the compact bone, and inclosing large, irregular spaces. This is the cancellous tissue bordering the marrow cavity. In the heads of long bones, and in

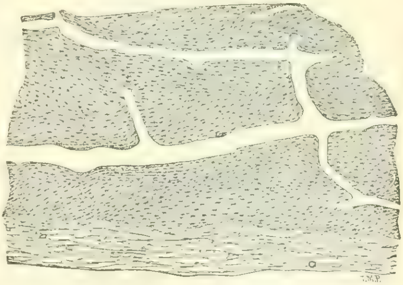

FIG. 638.—Longitudinal Section of Human Tibia, Decalcified and Mounted in Glycerin. (× about 20 and reduced.)

most short or irregular-shaped bones the cancellous tissue occupies the entire central portion.

If, now, we study more closely the minute structural features of the bone, we find in the first place that the Haversian canals, as seen in transverse sections of the bone, vary considerably in size and shape. Some are large, others small; some are round, others oval, others irregular in shape. In many cases, however, the oval shape of the Haversian canals and of their systems of lamellæ appears to be due to the obliquity of the section. In some cases the canals lie in the centre of the systems, in others near the side. Sometimes the Haversian systems are complex, one set of concentric lamellæ seeming to have encroached upon the space formerly occupied by another (Fig. 639). Furthermore, the borders of many of the Haversian systems, where these abut on one another or upon the intermediary systems, appear scolloped or jagged. This appearance will be explained below, when we consider the growth of the bone.

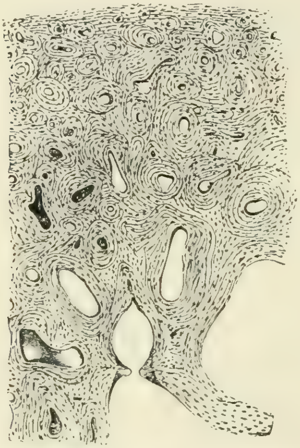

FIG. 639. Transverse Section of a Bone (the Ulna Deprived of Its Earth by Acid. (Sharpey.) Magnified 20 diameters. Haversian systems of canals and concentric lamellæ.

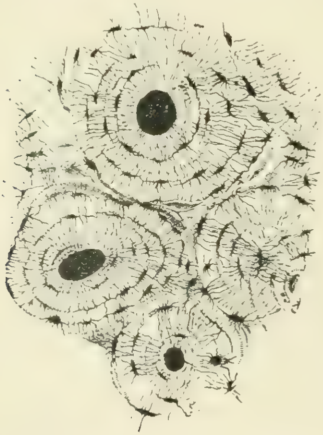

FIG. 640.—Transverse Section of Compact Tissue of Humerus. Magnified about 150 diameters and then slightly reduced. (Sharpey.) Three of the Haversian canals are seen, with their concentric rings; also the lacunæ, with the canaliculi extending from them across the direction of the lamellæ. The Haversian apertures had become filled with air and débris (from the grinding), and therefore appear black in the figure, which represents the object as viewed with transmitted light.

Turning now to the bone cells and the spaces in which they lie—the lacunæ—we find that some other mode of preparation is necessary than that of mounting sections of decalcified bone in glycerin, because the whole extent of the cell spaces is not revealed, on account of their partial filling by the mounting medium.

If, however, we take a bone which has been macerated and dried, to remove the fat and other soft tissues, and prepare thin sections by grinding and polishing them, and then mount them in hard balsam, which is melted, and, after the section is enclosed, cooled so quickly that it does not have time to penetrate far into the tissue, the full extent of the cell cavities is revealed. For all the spaces are now filled with air, which gives them a dark appearance by transmitted light. In a section thus prepared (Fig. 640), it will be seen that the lacunæ are elongated, mostly fusiform, irregular cavities, lying between and in the lamellæ, and that from these minute branching canals, called *canaliculi*, pass off, piercing the lamellæ and forming frequent communications with the canaliculi of neighboring lacunæ. The canaliculi which pass out from the lacunæ lying near the Haversian canals pierce the walls of the latter and open into them. The canaliculi of neighboring Haversian systems, however, do not, as a rule, communicate with one another.

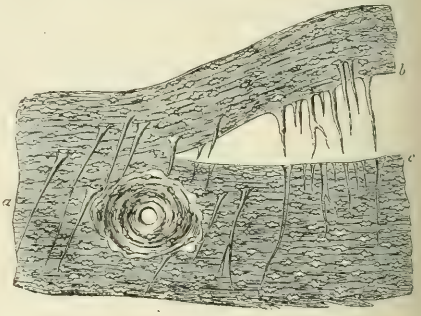

FIG. 641.—Section through the External Table of a Decalcified Human Parietal Bone. *a*, Sharpey's fibres in their natural position; *b*, fibres which have been pulled out of the underlying basement substance, *c*. (After H. Müller.)

In the lacunæ, as may be seen in carefully prepared thin sections of decalcified bone, lie the flattened and, in some cases, branching bone cells. To what extent the branches of the cells pass into the canaliculi is not yet fully established. The bone cells have large nuclei and finely granular bodies.

According to von Ebener, Sharpey, and others, the basement substance of bone is not homogeneous, but is permeated by exceedingly minute decussating fibrils, similar to those of the basement substance of ordinary fibrillar connective tissue. Certain of the lamellæ, particularly those of the circumferential and intermediary systems, are pierced by bundles of delicate fibrils, which pass perpendicularly or obliquely through them. These fibre bundles, called *Sharpey's fibres*, may be seen projecting from the inner side of small bits of bone torn forcibly away from one another, near the surfaces of decalcified bones (Fig. 641) as well as in very thin sections. These

Sharpey's fibres, as will be seen when we come to the development of bone, are the remains of the old fibrillar connective-tissue matrix in which the bone is formed.

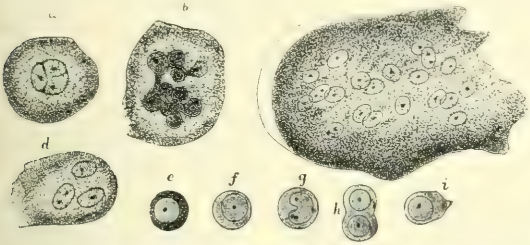

FIG. 642.—Cells of the Red Marrow of the Guinea-Pig. Highly magnified. (Schäfer.) *a*, A large cell the nucleus of which appears to be partly divided into three by constrictions; *b*, a cell the enlarged nucleus of which shows an appearance of budding into a number of smaller nuclei; *c*, a so-called giant cell or myeloplaxe with many nuclei; *d*, a smaller myeloplaxe with three nuclei; *e–i*, proper cells of the marrow.

2. *The Periosteum* is a fibrous sheath surrounding the bones, except over their articular surfaces. It consists of moderately dense layers of fibrillar connective tissue containing numerous blood-vessels, which ramify in the outer portions and finally enter the bone through the Haversian canals. There is a considerable number of elastic fibres in the inner portions of the periosteum, and it contains an abundant system of lymphatic vessels. In the growing bone irregular layers of large granular cells, called osteoblasts, lie in the inner layers of the periosteum, and between it and the bone. The periosteum contains a few nerves, which chiefly pass from it into the bone tissue.

3. *The Marrow* is a complex tissue which fills the large central cavities in the shafts of the long bones, the spaces in the cancellous tissue, and the larger Haversian canals. Marrow tissue varies considerably in its appearance and structure in adults and in the young, as well as in different bones in the adult. In the adult the marrow in the shafts of long bones consists of blood-vessels and a delicate connective-tissue reticulum which supports a great abundance of fat cells and a varying number of small spheroidal cells scattered between the fat cells. Such marrow has a yellow appearance from the fat which it contains. In the cancellous tissue of both long, irregular-shaped, and short bones in the adult, and in all of the bones in young animals, the marrow is red in color, and contains comparatively few fat-cells. Red marrow consists, like the yellow marrow, of blood-vessels, lymph vessels, and a delicate reticular framework whose meshes are more or less filled with cells. These cells are of several kinds (see Fig. 642). There are abundant small spheroidal cells with nuclei, which are very large in proportion to the size of the cell body; and between these and considerably larger cells, also with large and often irregularly shaped and sometimes double nuclei, there are numerous intermediate forms. All of the above forms are very abundant in red marrow, and constitute the *marrow cells* proper (Fig. 642). Then we find, much less frequently, and in varying numbers in different bones of the same animal, and in the bones of different animals, much larger, usually multinucleated cells, the so-called *myeloplaxes* or giant cells (Fig. 642). These myeloplaxes, although always large, vary considerably in size and shape, and in the number of their nuceli. The nuclei are apt to be collected in a compact mass near the centre of the cell, and often present quite bizarre and indescribable shapes. Finally, red marrow contains, in varying number, small nucleated cells, which bodies have the color and general appearance of red blood cells, the so-called *nucleated red blood cells*, and small spheroidal cells whose bodies contain larger and smaller particles of pigment, and a moderate number of fat cells.

THE DEVELOPMENT OF BONE.—It will be possible within the limits of this article to give only a very brief general description of the somewhat complex way in which bone is formed. It is customary to describe the development of bone as occurring in three ways, or, speaking more correctly, to describe three phases of bone development. These are *intracartilaginous, intramembranous*, and *subperiosteal*. It should be borne in mind, however, that the essential nature of the process is the same in all.

Intracartilaginous Ossification.—Most of the long and irregular-shaped bones in the body consist, at an early period of life, of masses of hyaline cartilage, which present, in a general way, the shape of the future bone. The transformation of these cartilage masses into bones is intracartilaginous ossification. This is always associated with a certain amount of subperiosteal ossification in the manner to be described below.

If we look at one of the cartilage masses which is to be converted into a long bone—at one of the bones of the finger or toe, for example (Fig. 643)—at a period when the process of ossification is about to commence, we notice that at the central portion of the mass the cartilage cells

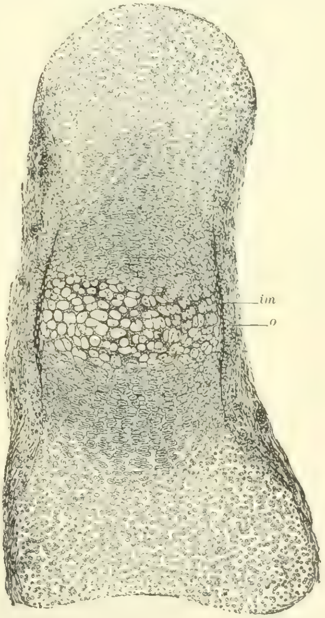

FIG. 643.—Section of Phalangeal Bone of Human Fœtus, at the Time of Commencing Ossification. (Schäfer.) The cartilage cells in the centre are enlarged and separated from one another by dark-looking calcified matrix; *im*, layer of bone deposited underneath the periosteum; *o*, layer of osteoblasts by which this layer has been formed. Some of the osteoblasts are already embedded in the new bone as lacunæ. The cartilage cells are becoming enlarged and flattened and arrayed in rows above and below the calcified centre. At the ends of the cartilage the cells are small and the groups are irregularly arranged; the fibrous periosteum is not sharply marked off from the cartilage.

are larger (Fig. 643) than in other parts, and closer together, and that the basement substance between them is finely granular from the deposition in it of salts of lime.

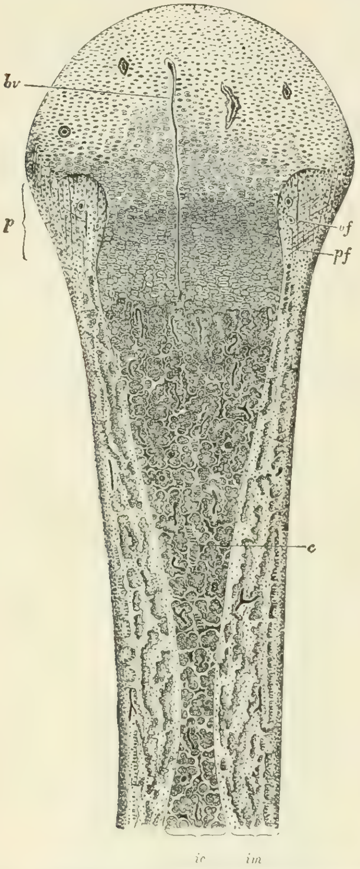

FIG. 644.—Longitudinal Section through the Upper Half of the Decalcified Humerus of a Fetal Sheep. Magnified about 30 diameters. (Schäfer.) *ic*, The part of the shaft which was primarily ossified in cartilage. One long, straight vessel (*bv*) passes in advance of the line of ossification far into the cartilaginous head; most of the others loop round close to the cartilage. At one or two places in the older parts of the bone, elongated groups of cartilage cells (*c*) may still be seen which have as yet escaped absorption; *im*, the part of the bone that has been ossified in membrane, that is to say, in the osteoblastic tissue under the periosteum. The subperiosteal layer is prolonged above into the thickening (*p*), which encroaches upon the cartilage of the head of the bone, and in which are seen, among numerous osteoblasts and a few blood-vessels, the straight, longitudinal osteogenic fibres (*of*), and some other fibres (*pf*), crossing them, and perhaps representing fibres of Sharpey.

While this preliminary calcification of the cartilage and the enlargement of its cells is going on, a shell of bone is forming around the middle of the shaft beneath the periosteum, and as the cartilage near the ends continues to grow and expand at the sides, the entire mass assumes somewhat of an hour-glass shape. Now the blood-vessels from the perichondrium—which has become a periosteum on account of the above-mentioned shell of bone which has been formed around the shaft—begin to advance in the central portion of the cartilage, and this becomes channelled out in irregular branching canals in the region of the enlarged cartilage cells, so that after a time a considerable portion of the central part of the shaft of the bone is permeated by a series of vascular canals. The general appearance of the bone at this time is seen in Fig. 644.

A closer examination at this period will show: (1) that the cartilage cells which lie in the region just beyond the advancing vascular canals have assumed a peculiar arrangement and are large; (2) that the basement substance of the cartilage in the same region is calcified; and (3) that thin layers of new bone are beginning to form along the edges of the vascular canals in the central portion of the shaft.

If we look at a similar bone at a somewhat later period, we find that while a layer of subperiosteal bone tissue of considerable thickness has been formed round the shaft, the central portions of the structure are also filled with irregular bony trabeculæ, between which lie the vascular canals or marrow cavities (Fig. 644); and, furthermore, that the cartilage cells toward the ends of the bone, in the region just in front of the advancing marrow cavities, are, as before, large and arranged in rows and lie in a calcified basement substance.

It is now necessary to look more closely at the changes in the cartilage which precede the ossification, and to study the exact way in which bone tissue is formed along the walls of the advancing marrow cavities.

If we look with a high power at a thin section of a carefully preserved and decalcified bone in the process of development, confining our attention for a moment chiefly to that region which lies along the ends of the above-described advancing marrow cavities, and for a short distance on either side, we find a condition similar to that represented in Fig. 646. At some distance toward the end of the bone from the medullary cavities the cartilage cells become flattened and are arranged in irregular rows, *b*; nearer the ossifying portions of the bone the cartilage cells are larger and more closely packed together; and finally, just beyond the ends of the advancing marrow canals, large cartilage cells are seen lying in elongated cavities in the basement substance, *c*. Each cavity contains several cells, which, in many cases, are separated from one another by narrow partitions of cartilage basement substance. Here and there along this region it will be seen that the marrow canals with their contained blood-vessels have opened into and become continuous with the spaces containing the large cartilage cells, and the latter have either disappeared or have assumed some different form. This occurs sooner or later, and usually at about the same time, all along this region, so that the advancing blood-vessels convert the spaces originally containing cartilage cells into vascular canals or marrow cavities.

If we look now at the region near the ends of the marrow canals, we find that these canals contain thin-walled blood-vessels, numerous small spheroidal cells, and larger cuboidal, ovoidal, or fusiform granular cells, which are apt to be arranged along the sides of the canals. These latter cells are the so-called *osteoblasts*, under whose influence the bone tissue is formed.

The exact way in which the bone tissue is deposited under the influence of the osteoblasts may be readily seen in very thin sections through the zone of ossification, which have been stained double with hæmatoxylin and eosin (see article on *Histological Technique*) and mounted in balsam. A small portion of such a section made transversely across the bone is represented in Fig. 645. Just beneath the osteoblasts which lie along the edges of the marrow canals thin crescentic shells of strongly refractile calcareous material—the basement substance of bone—are formed. These shells grow thicker and thicker, and rise up around the sides of the osteoblasts. They are pierced by delicate canals, which are to form the canaliculi. Gradually the entire osteoblast, which has become somewhat flattened and jagged in outline, is enclosed by the bony basement substance and becomes a bone cell. This process goes on around the osteoblasts, which lie side by side all along the walls of the marrow spaces, so that the latter are presently enclosed by an irregular wall or encasement of new bone. Upon this, new layers are deposited, so that gradually the marrow spaces grow narrower and narrower, and finally contain only blood-vessels and a few marrow cells. This gradual bony thickening of the walls and narrowing of the marrow spaces may be seen by following the tissue in a longitudinal section from the line where ossification commences, near the distal ends of the marrow spaces, toward the centre of the bone where the process is oldest.

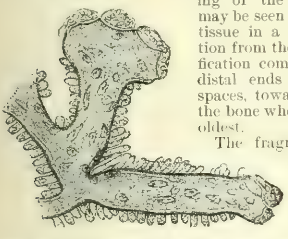
FIG. 645.—Bony Trabecula from the Lower Jaw of a Calf Embryo, with Howship's foveolæ and giant cells at the ends where absorption is proceeding and osteoblasts covering the sides where bone is being deposited. (Kölliker.)

The fragmentary remains of the old basement substance of the hyaline cartilage persist for some time, surrounded by the new-formed bone; but they grow smaller and smaller as more bone is formed, and are finally absorbed and altogether disappear.

Thus the ossification of the cartilages advances toward their ends, preceded always by a rearrangement and proliferation of the cartilage cells, and by calcification of its basement substance. What the exact purpose is of the temporary calcification of the cartilage basement substance just in advance of the ossification line we do not know, nor is it certain what becomes of the cartilage cells when the vascular canals finally open into the spaces in which they lie. Some observers believe that they disintegrate and are absorbed; others, that they become osteoblasts, or other marrow cells. Equally uncertain is the origin of the osteoblasts, and the consideration of the more or less well-founded conjectures as to their genesis would lead us beyond the scope of this article.

After a time new centres of ossification are formed near the ends of the long bones, in the epiphyses, from which bone formation proceeds in the manner above described. At length the zones of ossification in the epiphyses and diaphyses approach one another, and are separated only by a narrow band of cartilage, which finally itself becomes ossified, and the epiphysis and diaphysis are joined to form a single bone.

Intramembranous and *Subperiosteal Ossification* vary only in details from the intracartilaginous. In the former case, the tissue in which bone is to form is fibrous and vascular; osteoblasts appear along the bundles of fibres which become calcified, and bone is formed around them in the above-described manner. Some of the fibrous bundles persist within the new-formed bone, as Sharpey's fibres. The bone tissue which is at first formed is arranged in irregular trabeculæ, which cross and interlace as did the connective-tissue fibres which it replaces, and encloses irregular vascular spaces or marrow cavities, which become smaller and smaller as successive layers of bone are formed around their sides. After a time the irregular trabeculæ and their enclosed marrow spaces become covered in by more uniform layers of bone. These, in the long bones, are the circumferential lamellæ, and in the flat bones, such as those of the skull, are the compact external and internal tables which enclose the diploë.

A pure intramembranous ossification is seen in the early stages of the formation of the flat bones of the skull. The subperiosteal ossification, on the other hand, occurs as above indicated, simultaneously with the intracartilaginous bone formation in the long bones, as well as at a later stage in the formation of bones which are originally laid down as membranes.

GROWTH OF BONE.—The growth of bones when they are once formed, either in membranes or cartilages or beneath the periosteum, is a somewhat complex process. They increase in thickness by a continued subperiosteal ossification. The increase in length of long bones goes on by the ossification in cartilage until, as above stated, the epiphysis is finally joined to the diaphysis.

The large central marrow cavity of long bones, which in the adult bone is itself much larger than the entire bone at an early stage of development, is formed by the absorption of the earlier developed intracartilaginous and subperiosteal bone. This absorption occurs under the influence of large, irregular-shaped, frequently multinuclear granular cells, called *osteoclasts*. Around these cells, as they lie against the bone tissue, the latter becomes absorbed in some way, so that little pits are formed in which they lie. These pits or depressions, which are of various sizes and shapes, are called *Howship's lacunæ*. On the side of the osteoclasts which lie against the bone there is, according to Kölliker, a shining striated border. The exact nature of the influence by which the osteoclasts induce the absorption of the bone is not well understood.

Not only are the central marrow cavities formed under the influence of the osteoclasts, but by an absorption of the bone in various places, and a subsequent new formation of it over the absorbed surfaces, a remodelling of the bone may occur, inducing the various changes in shape which growing bones present. This process of absorption and redeposition of bone goes on, not only on the surfaces, but in the substance, even of compact bone, during early and adult life, inducing the minor changes which occur at this period. The intermediary systems of lamellæ, above described, as seen in transverse sections of long bones (Fig. 646), are, in many cases at least, the remains of older lamellæ which have been partially absorbed; the absorption spaces having been afterward filled in by new Haversian systems. What the conditions are whose fulfilment determines now an absorption and again a new formation of bone, or exactly what the origin

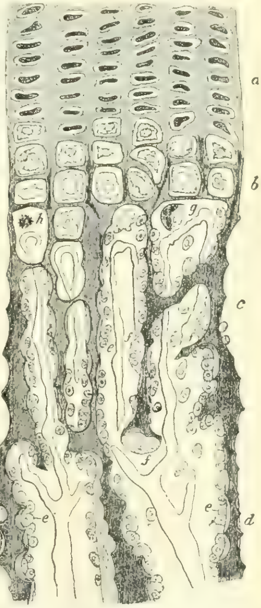

FIG. 646.—Part of a Longitudinal Section of the Developing Femur of the Rabbit. Magnified about 350 diameters. (Klein and Noble Smith.) *a*, Rows of flattened cartilage cells; *b*, greatly enlarged cartilage cells close to the advancing bone, the matrix between being partly calcified; *c*, *d*, already formed bone; the osseous trabeculæ being covered with osteoblasts (*e*), except here and there, where a giant cell or osteoclast (*f*) is seen, eroding parts of the trabeculæ; *g*, *h*, cartilage cells which have become sunken and irregular in shape.

of the osteoclasts is, and what their relation to the osteoblasts, we can, in the present state of exact knowledge, do little more than conjecture.

Consult, for the bibliography of the histology, development, and growth of bone, Quain's "Anatomy," vol. i. part ii., tenth edition, and the "Index Catalogue of the Library of the Surgeon-General's Office, U. S. A.," vol. ii.

T. Mitchell Prudden.

BONE. (PATHOLOGICAL.)—Bone, like all tissues, is subject to a continuous waste and repair. New bone is constantly formed and the old absorbed; and while in the adult these processes may be very slight, under the influence of pathological conditions they become very marked; hence the conditions known as pathological apposition, absorption, and transformation of bone. Apposition occurs by the formation of bone from the periosteum. The deeper layers of periosteal cells become converted into large epithelioid cells, the so-called osteoblasts, which later become irregular in shape; the intercellular substance becomes calcified and thus new bone is formed. The new bone may be spread out over the surface of the old, and become firmly attached to it, or it may be limited to a small portion of the surface of the bone. In the first case the process is called hyperostosis and exostosis; in the latter, the processes of new bone are called osteophytes.

Absorption or resorption of bone occurs at the medullary surface and is due to the activity of the large multinucleated cells known as osteoclasts. Occasionally this may occur at the periosteal surface, and we have the surface of the bone becoming irregular and porous—osteoporosis. This occurs occasionally in the very aged, in the bones of the calvarium, as the result of senile atrophy, or it may be secondary to inflammatory exudates, tumors, aneurisms, etc., which exert pressure upon the bone.

Transformation of bone is brought about by a combination of apposition and resorption. By means of these processes the form of bones is changed to meet pathological conditions and changes in function. This is more particularly true of the size and direction of the columns of bone in cancellous structures. If the amount and direction of the load to be borne by the bone become changed, then will the thickness and direction of the columns of bone become changed in the direction of the static demand. By reason of this characteristic of bone, such great artificial deformities are produced as are seen, for instance, in the Chinese foot.

Regeneration of bone is seen following every fracture. Every solution of continuity in bone is followed by the formation of new bone, not only sufficient to replace the defect, but also enough to form a large mass surrounding the fracture (callus).

In fractures of long bones, one differentiates an internal callus formed by the medullary structures, and an external callus formed by the periosteum. This new bone or callus remains intact until the function of the bone is resumed. Later on, that portion of the callus which is not situated in the direction of the load-bearing lines becomes absorbed, and the form of the new bone, just as that of the old, becomes changed to meet the static demands made upon it by the function of the bone—*i.e.*, that of bearing a load.

Osteomalacia is a chronic disease of bone, occurring in adults and most frequently in puerperal women; it is attended by a progressive softening and absorption of bone beginning in the centre and extending outward. The process is followed either by fracture or by deformity of the bones affected. It differs from rachitis in this, that while in the latter we have a deficient deposition of lime salts in newly formed bone, in osteomalacia bone which is already formed is deprived of its earthy material and absorbed. The changes that occur in the bone are not due to any active process on the part of the bone tissue itself. There are no active changes to be discovered in the bone cells. The only thing to be found in the lacunæ is the occasional presence of droplets of fat, which is evidence of a passive destruction of the bone cells.

In the medullary tissue, however, there are to be seen evidences of very marked, active proliferative processes. This is to be observed in the marrow of the long bones, in the medullary tissue of spongy bone, and also in the Haversian canals, which latter normally contain very little medullary tissue. This tissue is the seat of a marked hyperæmia which has converted it into a bright red, succulent tissue, free from fat and extremely rich in proliferating cells. All the medullary tissue seems to have the appearance of the red marrow of infantile bone. This tissue pushes its way outward at the expense of the adjacent bone, first depriving it of its lime salts and later causing its complete absorption.

Thus the compact bone of the diaphysis is converted into spongy bone by the enlargement of its Haversian canals; the trabeculæ of spongy bone are absorbed. If the process continue long enough there remains little of the bone except marrow and periosteum; so that it has been converted into a soft, decalcified, sausage-like mass of marrow, that is held together by the periosteum with perhaps a thin, paper-like layer of bone beneath.

The process may be distributed over a period of several years with occasional cessation. In such an event the medullary tissue loses its signs of active proliferation, the hyperæmia diminishes, and the tissue appears as a yellowish, fatty mass, or as a pale, gelatinous, mucoid, semi-fluid material. In the latter event many of the cells have undergone mucoid degeneration, and if this has been extensive it may have led to the formation of mucoid cysts. This period of quiescence may again give place to a renewed activity as before and to a further destruction of the bone.

This process has a certain resemblance, in activity, to that of inflammation, but the phenomena that attend either acute or chronic inflammation of bone are never present. We never find either suppuration or the formation of new bone.

The cause of decalcification of bone in this disease has been sought for chemically. Some investigators have found an excess of lactic acid in affected bones, and also in the urine, and the solvent action of this acid has been brought forward as the chemical agent which brings on decalcification. Other observers have failed to find this excess. The amount of gluten is diminished in the bones affected. There has been found in the urine a peculiar albuminous substance supposed to be derived from the organic substance of bone.

The bones of the pelvis and of the spinal column are most frequently affected, then come those of the thorax, and of the lower and upper extremities. The bones of the head are very rarely the seat of the disease; the teeth are never involved.

In the non-puerperal cases, the predisposing causes are malnutrition and living in dark, damp houses.

Osteomalacia has been observed in animals who are badly fed and stabled in dark, damp places.

Osteomalacia is a comparatively rare disease. It is rarely seen in England and America; it is more frequent in Germany than in France. In some parts of Germany the disease is more frequent than in others; thus in the Rhine valley and in Southern Germany the disease is more common than in other districts.

The preponderance of puerperal females affected is very striking. Thus of one hundred and thirty-one cases gathered together in the report of Letzmann, in 1861, eighty-five were in women who became ill either during pregnancy or during the puerperal period. Repeated pregnancy and prolonged nursing in poorly nourished women predispose to the disease.

In all of these puerperal cases the disease began in the bones of the pelvis, and in many it was limited to that region. It is therefore highly probable that the great circulatory changes in the pelvis attending pregnancy have a decided influence on the causation of the disease. Fehleisen regards the disease as a reflex trophoneurosis of the blood-vessels of bone, causing a dilatation and proliferation of the marrow at the expense of the bone, and having its origin in the ovaries. The removal of the

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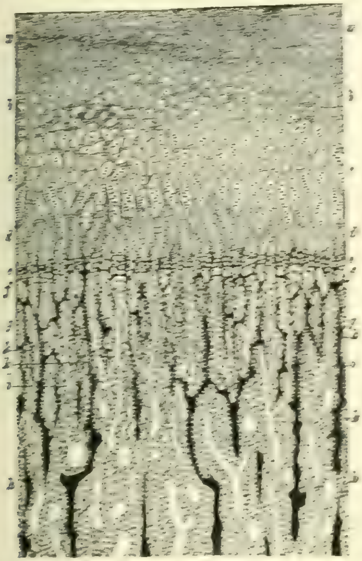

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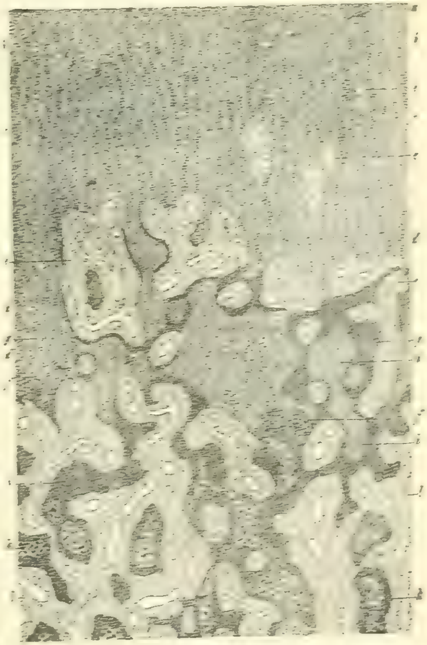

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above, below, and at the circumference, is enlarged and irregular. It is this which forms the irregular enlarged ends so characteristic of the disease. The zone of hypertrophied cartilage cells as well as the columnar zone is enormously enlarged. There is also a more or less complete absence of the zone of calcification of the cartilaginous groundwork, and in addition there is a great irregularity in the formation of the vascular, medullary canals. These have pushed their way into the cartilage in an irregular manner as though unrestrained by the presence of a firmly calcified groundwork.

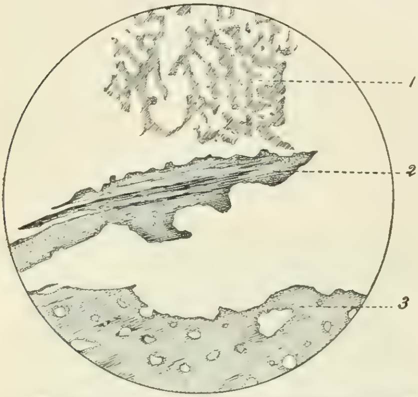

FIG. 649. Necrosis and Inflammatory Hyperplasia of Bone. (After Boyce.) 1, Spongy new bone; 2, remains of shaft; 3, sequestrum. (Slight enlargement.)

The persisting columns of cartilage are gradually converted into an "osteoid" tissue, made up of cells derived from the medullary tissue and a fibrillar, uncalcified groundwork. This osteoid tissue will show in numerous places islands of persisting cartilage. The zone of osteoid tissue may attain a length of 15 mm.; it is a firm, elastic connective tissue, but it bends under pressure. It differs from bone in that the cells have not the same regularity of arrangement, and in the absence of earthy material in the groundwork.

At a varying distance below this zone we finally come upon a zone in which columns of osteoid tissue are becoming converted into bone by the calcification of the groundwork.

Inflammations of bone occur in the periosteum, in the marrow, or in the joints; that is, always in those portions of the bone which are well supplied with blood-vessels. They are as a rule due to hæmatogenous infection or to trauma, although occasionally they may be brought about by extension from neighboring tissue. If the inflammatory process is of any considerable degree, or lasts for a considerable time, it is always followed by changes in the bony substance itself. This, as a rule, is of a retrograde character, *i.e.*, leading to destruction of bone. If the inflammation is of a highly infectious, purulent character, the connective tissue affected becomes dissolved, the vessels become thrombosed and are destroyed, and the bone becomes necrotic. If the inflammation is less severe in character, if it is accompanied by considerable cell infiltration and the formation of new vessels (granulation tissue), there follows a gradual solution of the neighboring bone or cartilage, an ulceration, or, as it is usually called, caries. As long as this inflammation keeps up, so long is there a gradual absorption of the neighboring bone or cartilage. If in the beginning of the inflammation there occurs necrosis of a certain portion of bone, there follows in the later stages, at the surface of this necrosed portion, a gradual absorption which has its greatest intensity at the border between living and dead bone, so that eventually the two become separated and there is formed a sequestrum. If the latter is not very large it may in the course of time become completely absorbed by the neighboring granulation tissue. Large sequestra, however, offer a great deal of resistance to this absorptive process and may remain for years. As long as the sequestrum is present so long will the inflammation keep up, even though the infection has been overcome. A piece of dead bone acts as a foreign body and is a sufficient irritant to keep up this chronic form of inflammation.

In addition to this destructive process in bone accompanying inflammation, every such process lasting for any considerable time is accompanied by a hyperplasia, which manifests itself partly in the vascular soft parts and partly in the bone itself. This occurs both in the immediate neighborhood of the inflammation and in surrounding portions of the bone. It leads to those processes which have received the names of hyperostosis, exostosis, osteophytes, and parostosis. The most excessive hyperplasia of bone occurs in those cases in which a large sequestrum remains as a source of irritation for months and years.

Of acute infections, *osteomyelitis* is the most severe acute inflammation of bone with which we have to deal. It occurs most frequently in young individuals, as a rule in one of the long bones, and is accompanied by fever, by a destruction of more or less of the bone, and by the formation of an abscess. The infection is either primary or secondary to one of the acute infectious diseases. As a rule, the immediate cause is the staphylococcus pyogenes aureus or albus. The process may begin either in the periosteum, or in the marrow of the bone. It very soon leads to the formation of pus and to the destruction of bone. In severe cases it may lead to the suppuration of the marrow of the entire diaphysis and to an extension into the cortex of the bone through the Haversian canals. It may occasionally break through the periosteum. If the inflammatory process is near a joint, the pus may be poured into the cavity thereof. Through the formation of septic thrombi in the veins, we may have multiple metastatic abscesses and death by pyæmia. Wherever we have had a suppurative inflammation, there is of course a death of more or less bone, but the extent of this necrosis depends upon that of the suppurative process. If this has been very slight, the necrosed pieces of bone may become absorbed, so that they may not be discovered. In more severe forms we may have a sequestrum comprising the entire diaphysis. According to the extent and seat of the necrosis there may be distinguished a total, a partial, a central, and a superficial necrosis. Very soon after the setting in of the suppurative process there will be formed at the border, between the dead and the living parts, a zone of granulation tissue. This leads eventually to the separation of the sequestrum. When this has become complete there will be present, within the bone, an abscess cavity containing a sequestrum. This cavity very often connects with the surface of the bone by means of an opening or fistula. The walls of this fistula are also covered by a layer of granulation tissue from the surface of which pus is being poured out. In the neighborhood of these areas of granulation tissue there will have occurred more or less hyperplasia of bone which leads to a thickening. If the bone has been destroyed in its entire thickness in the beginning, then this hyperplasia occurs of course only in the periosteum, which thus surrounds the sequestrum with a firm, bony capsule. In cases of partial necrosis, however, new bone is formed both from the periosteum and in the interior of the bone. Small sequestra may in the course of months be absorbed; large ones constitute an irritant sufficient to maintain an inflammatory process for years, and they can be gotten rid of only by operative procedure. After the removal of the sequestrum the wound cavity is closed by means of granulation tissue, which later may be replaced by the formation of true bone through the activity of the periosteum or of the bone marrow.

Tuberculosis of bone gains entrance either through the marrow, the periosteum, the joint, or the surrounding soft parts. The most frequent method of development is that of a small tuberculous nodule which forms in the marrow of an epiphysis. This undergoes caseation and softening and eventually breaks through the bone to the surface, thus either entering into the joint or breaking through the periosteum. The process is of course always accompanied by caries, at times of considerable extent. A notable example of this is seen in tuberculosis of the spine, where the bodies of one or more vertebræ may be destroyed. This of course leads to the extensive deformities that we see in this disease (Pott's disease). After such a bone abscess (for this it really is) breaks through the periosteum, there are formed collections of pus in the surrounding tissues, particularly between the muscles. These sometimes reach an enormous size, and may through the influence of gravity dissect their way for a considerable distance through the body before reaching the surface.

In miliary tuberculosis, we have numerous tubercles in the bone marrow. Occasionally the tuberculous process affects the long bones of the hand or the foot in a very slow and chronic form, leading to resorption from the internal surface and apposition at the periosteal surface, and in this way producing certain peculiar spindle-shaped swellings that have been termed spinæ ventosæ. This may be followed by the occurrence of necrosis and the formation of sequestra and fistulæ, but in most instances the swelling eventually disappears.

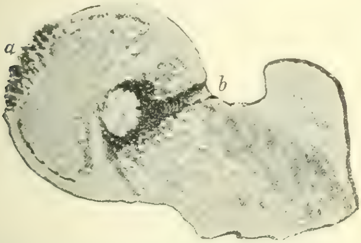

FIG. 650. Severe Tuberculous Coxitis. The disease has broken through the cartilage at *a*. In the region of the neck is a sequestrum about the size of a cherry stone lying free in an abscess cavity connected with the joint by means of the fistula *b*. (After Krause.)

Syphilis occurs in bone in three forms:

(1) Gummatous formations affecting both the periosteum and the marrow. In the periosteum, the process is accompanied by a destruction of bone, of such a character that sharply defined defects are produced—the so-called caries sicca. This occurs more especially on the calvarium. Occasionally one finds in the neighborhood of these bony defects new growth of bone.

(2) Hyperostosis. This occurs either in the form of hard, ivory-like thickenings in the compact bone, or in the formation of irregular exostoses or osteophytes. The latter form is found more especially in the tibia.

(3) Congenital syphilitic osteochondritis. This in its severe form is accompanied by the formation of irregular growths in the zone of growing bone, growths which have undergone a fatty and calcareous degeneration, and which may have the character of true gummata. In the lighter forms we have simply a calcification of the zone of cartilaginous hypertrophy at the epiphysis, marked by a sharp, yellowish-white line, and accompanied by a slight sclerosis of the neighboring bone. This affection is always present in congenital syphilis, but may disappear, so that a few weeks or months after birth it may not be found.

Actinomycosis of bone begins, as a rule, in the marrow by the formation of granulation tissue, which causes an absorption of bone from the inside and is accompanied by an apposition of bone on the periosteal side. In this way we may have large projections from the surface of the bone which, in decalcified and macerated preparations, will show on the inside the formation of a number of cysts. At times the actinomycotic process pushes through the bone to the periosteum, destroying this without being accompanied by the apposition of new bone, so that there will be produced a caries in the form of an osteoporosis.

Sarcomata are frequently found in bone. They occur either in the marrow (myelogenous sarcomata) or in the periosteum (periosteal sarcomata). Those that occur in the marrow of the bone produce, by the absorption of bone from the inside and apposition of bone from the outside, enlargements of the bone which attain at times enormous size, and in which we have the tumor mass surrounded by a more or less well-developed capsule of bone. Later on, even this capsule becomes either partially or totally destroyed by the pushing of the tumor through the bone. The tumor is as a rule of the round-celled variety, containing usually a large number of multinucleated giant cells. These giant cells may at times attain such enormous size as to be visible to the naked eye. Occasionally, however, they may be entirely absent. These sarcomata are exceedingly apt to recur after an excision or amputation. Periosteal sarcomata have, as a rule, a very considerable framework of bone in which the sarcomatous masses are enclosed, so that they are more aptly termed osteo-sarcomata. Occasionally also they have in addition a certain amount of cartilage, when they are called osteo-chondro-sarcomata. They are, as a rule, of the spindle- or small round-celled variety without giant cells. They are exceedingly apt to form metastases, especially in the lungs. *Simon Pendleton Kramer.*

BONE, PLASTIC SURGERY OF THE.—Defects in bone heal so slowly and imperfectly that it is no wonder surgeons of very early times tried to assist nature in their repair. There is some reason to suppose that such efforts were successful in India more than five hundred years ago, while a Peruvian skull antedating no one knows how long the discovery of America has, according to McGee, been found with a silver plate sunk in its substance to protect the opening made after trephining. The condition of the bone shows that the plate rested in it for a considerable time before death.

Despite this long history, and the very numerous experiments which have been carried out in recent years with the aid of a fuller knowledge of asepsis, the subject of repairing large defects in bone is still very imperfectly understood.

The indications for bone transplantation or some similar procedure are:

1. To afford a protection to underlying organs, notably to the brain after extensive removal of the cranium by accident or operation.
2. To preserve the normal contour of the parts—for instance, after loss of the bridge of the nose or half of the lower jaw.
3. To maintain the continuity of a bone so that the power of a limb shall not be lost.
4. To shorten the time of recovery, for a deep cavity in a bone—for example, in the head of the tibia—heals very slowly and often imperfectly.

In considering this subject of plastic operations upon bone, it is well to remember that osseous tissue has only a slight regenerative power, while the power of the periosteum to form new bone is very great indeed. This is constantly illustrated by the repair of comminuted fractures, the injured bone being restored to something like its former condition, though many fragments may have been lost. One must therefore accept with great caution accounts of the incorporation into the structure of a bone, of bone chips or decalcified bone which surgeons have introduced into a bony gap to hasten recovery. The new bone under such circumstances may have come from periosteal flaps which were not destroyed by the accident.

The integrity of the periosteum is of chief importance in the maintenance of osseous tissue. If, therefore, a flap of bone and periosteum can be so cut as to remain attached to the soft parts, it may be nourished through the pedicle until it unites in a new situation. Many useful operative procedures have been founded upon this principle, but the field is a limited one, because superfluous bone, which may be utilized for the bone flap, will often be wanting in the immediate neighborhood of the bony defect.

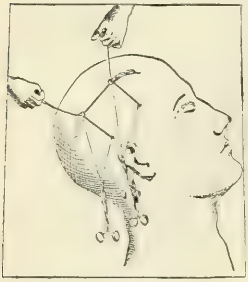
FIG. 651.—Osteoplastic Resection of the Skull by Means of a Gigli Wire Saw. (Gigli.)

Such an osteoplastic resection of bone has been performed upon the skull, upon the bones of an extremity, to restore a deficient nose, to supply an anterior plate to the trachea, et cetera.

Osteoplastic Resection of the Skull.—This operation has been devised to give the surgeon more space than can be safely obtained by trephining. As practically the whole bone is replaced, the flap may be made very large without risk of leaving the brain unprotected. The operation, which may be carried out in various ways, aims to cut through the bone and soft parts on three sides of a rectangle, or three-quarters of a circle, and then to break the bone on the fourth side without injuring the soft parts or disturbing the vitality of the large bone flap. It has been many times successfully carried out in the past few years. Fig. 651 shows the method of cutting a flap by means of a Gigli wire saw which is passed through very small trephine openings and saws the bone from within outward.

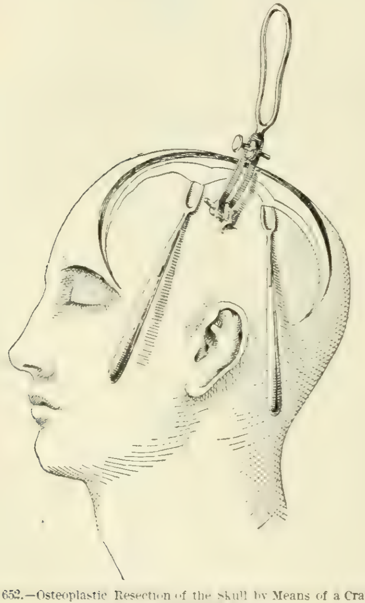
FIG. 652.—Osteoplastic Resection of the Skull by Means of a Craniotome. (Codivilla.)

The bone flap may also be cut by chisels or by a craniotome.

When the operation upon the brain is completed, the operator has only to bend back into its original position the flap of skin and bone and to fasten it there by a few sutures. Primary union usually results.

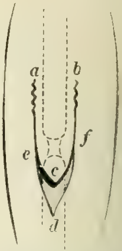

FIG. 653.—Osteoplastic Resection of the Tibia with Retraction of Skin and Bone Flap. (Mueller.)

One of the first operators to make use of a flap of skin and bone was Koenig, whose rhinoplasty, carried out by means of a flap cut from the forehead and twisted downward and stitched in position to make a new nose, is too well known to need detailed description. In a similar manner, other surgeons have successfully operated to close defects in the skull, by taking a flap of the skin and the outer table of the bone and swinging it around over the defect. If the skull is thin it is difficult to split it in this manner; but the periosteum can always be obtained.

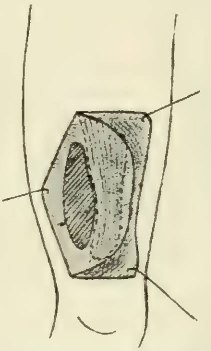
FIG. 654.—Closure of a Defect in the Femur by a Plastic Operation. Skin and fascia reflected; flap of muscle and periosteum marked out. (Ap Schulten.)

Osteoplastic operations upon an extremity, a pedicle being employed to keep up the nutrition until the flap unites in its new position, were described in 1856 by Jordan and Nélaton. Since that time they have many times been successfully carried out. The flap may either be twisted on its pedicle as is done in Koenig's rhinoplasty, or it may be cut from the distal fragment of a defective bone, and retracted so as to fill the gap between the fragments, as is shown in Fig. 653.

A defect in the femur, several inches in length even, may be closed in a similar manner by a flap of muscle and periosteum. The steps in the process, as described by Ap Schulten, are the preparation of the cavity in the bone consisting of free exposure, irrigation, and tamponade with sterilized gauze. Three or four weeks later, when the cavity is lined with healthy granulations, it is cleaned, the site of the proposed flap is exposed by longitudinal and transverse incisions, and a tongue-shaped flap of muscle and periosteum is cut, with its base upward whenever possible, although this is not absolutely necessary. The edge of the bony cavity is cut away at the place

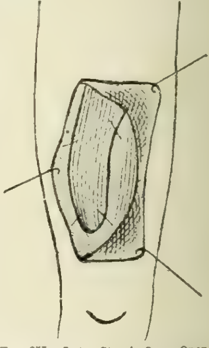
FIG. 655.—Later Step in Same Operation. Flap stitched in position to close the defect in the femur. (Ap Schulten.)

at which the flap is to be bent over it, and a couple of stitches are inserted to hold the flap in position. The drawings (Fig. 654 and 655) sufficiently illustrate the method of procedure.

From the plastic operation already described it is only a short step to one which splits a bone in order to utilize the two portions to make up for the lack of its fellow.

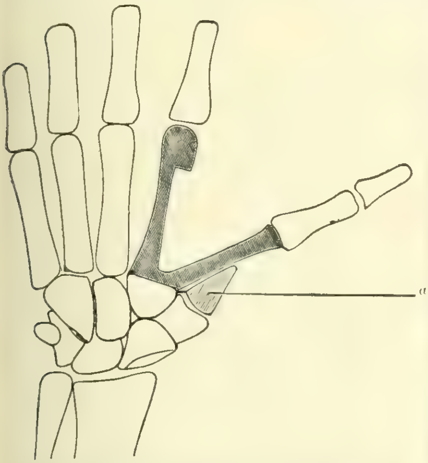

FIG. 656.—Splitting of the Second Metacarpus and Utilization of One of the Parts as a Substitute for the Metacarpus of the Thumb. (K. Cramer.) a, Remains of the metacarpus of the thumb.

This has been successfully performed upon the metacarpals and metatarsals, and the ulna has beeen successfully split to piece out the radius.

The use of a less important bone for its fellow, as of the fibula to make good a defect of the tibia, is founded upon the same principle as the operations hitherto described. One of the well-recognized operations for cleft palate consists in chiselling free a strip of bone along either margin of the cleft, and by stitching them in the middle to convert one large cleft into two smaller ones, which can later be closed by a plastic operation upon the soft tissues.

This osteoplastic principle has recently been employed in a most ingenious way to close a defect in the anterior wall of the trachea. Schimmelbusch cut a flap from the sternum of a child aged thirteen years, and inverted it, so that the skin surface was directed toward the lumen of the trachea. The bony surface turned outward was covered with skin from the neck. The wound healed nicely and the plate of bone prevented the sinking in of the anterior wall of the trachea during inspiration, and consequent suffocation which is noticed when such a defect is closed by skin only. König operated successfully upon a seven-year-old child, taking a skin-and-bone flap from the clavicle. The bone sloughed out, but the periosteum lived and became stiff enough to keep the lumen of the trachea intact. Auc describes a similar operation, or rather series of operations, successfully carried out by Sklifossowsky under less favorable circumstances upon a boy aged fourteen years. There was stenosis of the trachea and larynx which had first to be overcome by plastic operations, the skin of the neck being utilized to cover the posterior defect in the tracheal lining. Then the sternal skin-and-bone flap was employed, as in the operations mentioned above. With this variation: the flap of bone was loosened and the skin flap was wrapped around it like a blanket and stitched there. When the wound had so far healed that the bone was completely surrounded by skin, the flap was turned upward and stitched in the tracheal gap. Necrosis of the bone flap was thus guarded against.

The use of a bone flap to heal a defect in bone is limited by the length of the pedicle and the supply of suitable bone in the neighborhood. It is obvious if a piece of bone can be transplanted without a pedicle, the field of this branch of surgery will be much wider. There will then be three sources of bone available, viz., other bones in the patient, the bones of other individuals, and the bones of animals. It seems certain that bone grafts from all three sources have healed in their new beds. Not only do the histories of these patients show that bone so transplanted may become part of the bony structure of the individual operated upon, and not simply remain as a foreign body which is tolerated by the surrounding tissues, but the *x*-ray affords the surgeon a means of actually demonstrating that the implanted fragment may persist and carry out the functions of the bone for which it is a substitute (Fig. 657).

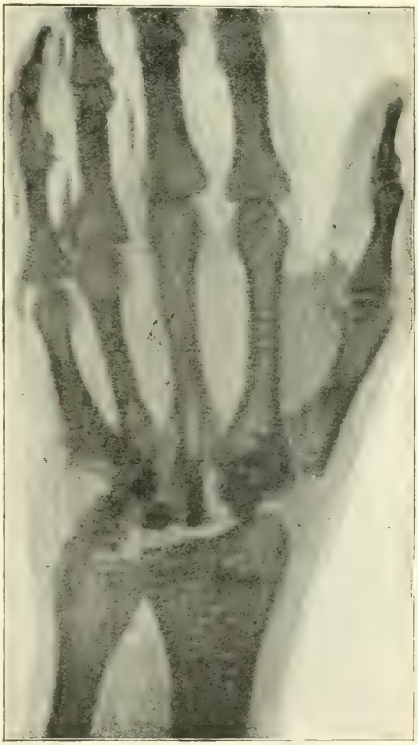

FIG. 657.—Radiographic Photograph of the Actual Condition of the Wrist After the Osteoplastic Operation Described in the Text. (Dubar.)

Dubar resected the wrist of a girl aged nine years for tuberculosis, and inserted in place of the carpal bones that were removed, five fragments from the lower ends of the femurs of a puppy aged eight days. The wound healed primarily. The limb was kept in a plaster-of-Paris splint for six weeks. All the motions at the wrist were preserved. Three years later a small focus of tuberculosis in the fifth metacarpal bone was curetted away. It did not communicate with the wrist. Two years afterward a similar lesion in the fourth metacarpal bone was treated in the same manner. After both of these lesser operative efforts the wounds healed perfectly. Six years after the operation upon the wrist a radiograph was taken (Fig. 657). This showed that the fragments of puppy bone had held their positions and had actually increased in size, fixed in the midst of new-formed fibrous tissue.

Kronacher inserted a piece of calf bone sterilized by boiling, to make good the defect in the first phalanx of the forefinger. The wound was drained and healed by granulation. The finger was kept in plaster of Paris for more than three months, and was finally stiff. New bone formed around the old, as was shown by a radiograph, and the length of the phalanx was nearly normal. The new bone in this instance may have come apparently from undestroyed periosteum.

Lane used a rabbit's femur to make good a congenital defect in the middle of the ulna of a child, splitting the femur and applying the two halves like splints, one to either side of the ulna. In a similar manner he supplemented a defect in an adult ulna resulting from an inflammation of the bone. The results were satisfactory, both patients obtaining perfectly useful limbs.

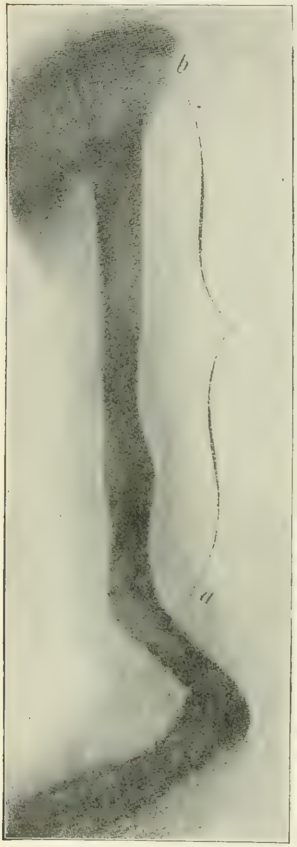

FIG. 658.—Radiograph of Arm, Showing Successful Transplantation of Piece from Tibia to Take Place of Humerus. *a b*, The portion of bone transplanted. (Klapp.)

Ricord removed a large osteosarcoma from the forehead of a woman and utilized the coccyx of a dog to fill the gap in the skull. Five years later the patient died of metastatic growths similar to the original tumor. There was no recurrence at the site of the original tumor and the coccyx was still in place and unabsorbed.

He also made use of the fourth metatarsal of a woman to correct a nasal deformity in the same patient. The operation was in every way successful, and five months later the bone was solid in its new position. Seventeen months after the operation its place had been taken by solid elastic tissue, which was firm enough to still hold the skin over the nose in correct position.

Bramann cut a piece from the tibia of a patient and used it to splice a defective humerus in the same individual. The operation succeeded.

But the most striking success which has thus far been recorded of bone transplantation is perhaps the case of which the radiograph is here reproduced (Fig. 658).

In this instance Klapp removed the greater portion of the humerus of a woman aged thirty years for a sarcoma which had so eroded the shaft of the bone as to bring about a spontaneous fracture. The periosteum was also removed. To fill this defect the operator chiselled a piece from the anterior part of the patient's own tibia nearly as long as her humerus and transplanted this long strip of bone, to which the periosteum was still adherent, to the arm, inserting its ends in the upper and lower extremities of the humerus, which still remained in their normal positions. The most careful asepsis was observed, but a suppuration took place in the arm, and a considerable part of the scar had to be reopened in three weeks. The wound then healed by granulation, and some weeks later a sequestrum a little over an inch long and not quite an inch broad came away. No further suppuration took place, the wound healed, and bony union took place between the remains of the humerus and the transplanted piece. This was shown by the fact that the patient could hold a three pound weight out at arm's length, as well as by the radiograph. The arm was not quite so strong as the other, but sufficed for the ordinary duties of the house. The accompanying radiograph was made nearly two years after the operation.

Though these are isolated examples of successful bone transplantation, and the failures have doubtless been many times more numerous, yet a few well-authenticated successes are sufficient to encourage surgeons to continue their efforts until the conditions under which success is to be obtained are better known. When they are thoroughly understood, a bone graft may be performed with better hope of success. *A priori* there seems to be no reason why a graft of bone from one individual to another of the same species, or a graft from one part of the human body to another, should not grow as well as a graft of skin, or of the thyroid gland. In transplantation of bone from man to man, the possibility of the transmission of disease ought not to be overlooked.

The operations thus far described are difficult of performance and they by no means promise any certainty of result. Is it not possible to close a defect in bone by some simpler method? For this purpose both organic and inorganic material have been used.

Filling Defects with Organic Material.—1. With blood clot.

The most accessible organic substance with which to fill a bone cavity is a blood clot. Schede proposed in this manner to shorten the time of healing. The method is practicable, if the asepsis is perfect, though the length of time required for the organization of the clot is greater than the early advocates of this plan supposed, and the final results are little if any better than those obtained by allowing the cavity to close by granulations. In suitable cases a still better plan is to cut away the edges of the cavity to such an extent that the skin and periosteal flaps may cover the bottom of the defect.

2. With decalcified bone.

Senn suggested decalcified bone as a suitable material to use in filling a bone cavity. It is of course easily sterilizable, and is well tolerated by the tissues. Little by little, if asepsis is perfect, the decalcified bone may be absorbed and its place taken by tissue of new formation, either bone or connective tissue as the case may be. Under such circumstances the permanent result is not better than a strong scar formed by granulation. If the decalcified bone is in a badly nourished portion of the body, it may resist absorption a long time, as shown by the following unique case narrated by C. L. Gibson: Decalcified bone chips prepared according to the directions of Senn had been packed into the cavity left in the head of the tibia after evacuation of a cyst. The skin healed and function and appearance were normal for four and one-half years. Then the scar became inflamed and some chips made their way out through the skin, leaving a sinus. The whole cavity was opened and the chips and loose granulations were curetted away. There was no perceptible change in the bone chips, nor was there any new formation of bone.

3. With calcined bone chips; with sterilized bone chips; with aseptic live bone chips.

The fate of an implanted bone chip has provoked a long and bitter discussion, carried on over a period of some years by Barth and David. The former claims, as a result of numerous histological examinations of specimens obtained from animals and man, that a transplanted bone fragment always dies and is succeeded by new-formed bone; while David claims that at least a part of the transplanted bone does not lose its vitality, but after a period of inactivity it becomes revascularized and lives again as truly as before its transplantation. It would seem that so well defined a problem as this might be easily settled, but the discussion has gone on for some years, without any definite conclusion, although several other investigators have studied the subject and have written upon it, some taking one view and some the other. Those who are interested in the details of this question, will find them fully discussed in the *Archiv für klinische Chirurgie*, 1896–99, an especially full article giving a résumé of those preceding it being one by Fischoeder in vol. lviii. of that magazine, p. 840.

One or two experiments are worth a passing notice. Morpurgo and Martini introduced plates of bone, freed from organic substances, into pouches made in connective tissue. There usually followed a growth of the living tissues into the calcic substance, exactly reproducing the bony structure. The experimenters looked upon this as a new formation of bone from connective tissue, under the influence of the lime salts. Zworykin went one step farther and was able to cause ossification in the heads of rabbits by the introduction of chemical mixtures of lime salts, simulating the mixtures found in normal bone.

It makes little difference to the surgeon, and less to the patient, whether the bone which fills in the gap in his skull is the implanted bone which has retained its vitality, or bone of new formation which has gradually eaten up the implanted bone, using its lime salts for the new bone cells. Indeed, in practical use calcined bone, which all must admit to be dead, is said by many surgeons to be better than chips of living bone. The bone for the purpose should be of a spongy character. The scapula of the calf answers very well for implantation in the skull.

Filling Defects with Non-Absorbable Material.—If the success of these implantation experiments depends not at all on the fact that the bone is alive, and altogether on the aseptic operation, and on the non-irritating qualities of the implanted foreign substance, why confine one's self to organic material?

Teeth may be filled with gold, silver, cement, etc., and no harm follows. Bullets and other foreign substances remain encysted for years. Why not fill bone cavities with some non-absorbable material? Theoretically this is possible, and practically it may be done provided the cavity is not a large one and asepsis can be secured. Stachow has made many experiments in this direction, and has reached the conclusion that a copper amalgam is the material best suited to this purpose. Plaster of Paris, cement, gutta percha, and other substances have been used with a limited success in man as well as in animals; but the chances of future suppuration, even long after the healing is complete, are very great. In certain situations hard foreign substances are well tolerated and are very serviceable. Thus Weir and others have used celluloid for supplying the nasal bridge, although the boat-shaped piece of celluloid is merely slipped under the skin and does not come in contact with the bones. The same may be true when a celluloid plate is inserted to cover the defect left by trephining, or after resection of the lower jaw, as described by Berndt. It was at one time the fashion to preserve a trephine button in salt solution, and to replace it before closing the wound. Experiments upon animals showed, however, that whereas the button might become firmly fixed in position, adhesions between it and the dura are almost sure to follow, even though the operation is of the simplest character. Foreign substances with a smooth surface do not offer such opportunities for firm adhesions, and hence celluloid plates are preferable. Most of the best-known continental surgeons early reported successful cases in which celluloid was thus employed, and with the backing of Fraenkel, Hinterstoisser, von Eiselsberg, Billroth, Winiwarter, Wölfler, and others, the procedure soon became generally known and practised in both Europe and America.

Monara prefers to use a thin plate of cartilage. He says that if its smooth surface is directed toward the brain, no adhesions between the membranes and the cartilage will result.

A hard foreign substance may be used as a guide to the periosteum in its attempt to form new bone. C. Martin made a skeleton of platinum-iridium wires the shape of the bone that was lost and succeeded in getting the periosteum to grow a new bone almost the shape of the old. Immobility is essential to the success of such procedures, and hence they yield better results in the forearm and leg than in the upper arm and thigh, since the sound bone acts as a closer splint than any external apparatus can possibly do. In Martin's successful cases, the supports remained permanently incorporated in the regenerated bones. As such apparatus usually needs fitting during the operation, the vise, files, pincers, and whatever other tools are required should be sterilized, as well as the instruments needed for the operation upon the patient. This is equally true when celluloid or other solid material is introduced. *Edward Milton Foote.*

BONE-SETTING.—In every country there is a class of irregular practitioners who make a living, and sometimes also quite an extensive reputation, by their success in restoring functional usefulness to crippled limbs. These individuals are, as a rule, most arrant quacks, knowing absolutely nothing of anatomy, or of the pathology of the conditions which they are called upon to treat, and yet they are often successful to a remarkable degree in curing certain joint affections which may have baffled the skill of the most experienced and able surgeons. These men are known as bone-setters, from their invariable assertion, made often through honest ignorance, that "the bone is out of joint, and only needs to be set." It is true that they frequently inflict most serious injury, which may lead to loss of limb or life itself, yet it is also undeniable that they sometimes restore a limb which might otherwise remain permanently crippled, or even be sacrificed as a useless incumbrance. Such being the fact, it is not the part of wisdom to seek to ignore the existence of bone-setters, or to allow their failures to blind our eyes to their successes; but we should rather study their methods, to learn wherein lies the secret of their triumphs, and then we may with benefit and without any loss of dignity imitate their treatment in suitable cases, easily avoiding, through a knowledge of anatomy and pathology, the pitfalls into which they, in their ignorance, so often plunge.

Dr. Wharton P. Hood[1] was the first to study intelligently the methods employed by bone-setters, and it is to him that most of our knowledge of this art, for art it is, though no science, is due. He defines bone-setting as "the art of overcoming, by sudden flexion or extension, any impediments to the free motion of joints that may be left behind after the subsidence of the early symptoms of disease or injury; perhaps, indeed, more frequently of the latter than of the former." The cases that most frequently fall into the hands of bone-setters, and are cured, to the joy of the patient, but to the discredit and loss of reputation of the regular practitioner, are those of slight fibrous ankylosis, of a degree sufficient to limit motion and impair the functional utility of the limb, yet not such as apparently to demand forcible rupture, an operation so unreasonably dreaded by many surgeons. In such a case, perhaps, some feeble attempts at passive motion are made. The joint is flexed cautiously and slowly, until the patient complains bitterly of pain; then the operator desists, orders the limb to be kept at rest, and bathed with lotions to subdue the inflammation excited by the strain put upon the adventitious bands. A few days later, when the heat and swelling have disappeared, the same manipulations are repeated, and followed again by inflammation and its treatment. After a number of repetitions of this sort the patient sees that he is no better than before, and refuses to submit his joint to any further manipulations. Then he becomes discouraged, limps around with the aid of a cane or crutches, and tries to bear philosophically the thought that he is a cripple for life. But at last some friend tells him of a wonderful cure performed by a bone-setter in a case apparently similar to his own, and in desperation he sends for the quack. The latter assures him that the bone is out and only needs to be replaced. He orders the joint to be enveloped for a time in flaxseed poultices, probably a procedure that contributes in no way to the success of the operation, and then on the appointed day meets his patient, seizes the limb, and with a quick motion flexes and extends the joint to its full extent, breaking up all the adhesions, and the patient finds that he is cured. The pain of the operation is but little greater than that inflicted by the regular practitioner in his feeble and ineffectual attempts to restore motility, and the resulting inflammation is usually slight or nil. The quack says that the bone is restored to its place, pockets his fee, and retires with glory.

This is no exaggerated picture, but is a true tale of what actually occurs in not a few instances, as many practitioners will sorrowfully admit. The good that bone-setters do is in these cases of partial ankylosis, and it is because they are unable to discriminate between the different conditions in which joint motion is impeded that they so often inflict irreparable injury. No surgeon would attempt forcibly to move an articulation which is the seat of strumous or tuberculous inflammation, yet this is what the bone-setter does with dire result. In most of the joints which can be benefited by forcible movements there is a tender spot, usually about the inner side, for which the bone-setter always feels, and the discovery of which is to him a sign of ultimate success. The motion of the joint is not absolutely abolished, but is limited in certain directions, and any attempt to pass this limit causes pain. The skin over the articulation is not hot, and all the other signs of inflammation, except perhaps a slight serous effusion, are absent. The following is an enumeration of the location of these painful spots, together with Mr. Fox's explanations of their occurrence, as given by Mr. Edward Cotterell in a very practical little work treating of the minor injuries of the limbs.[2] 1. "Over the head of the femur, in the centre of the groin, corrresponding to the ilio-femoral band of the capsular ligament (which is most severely stretched when the thigh is over-extended, as when the trunk is flung violently backward, the commonest cause of a sprained hip). 2. For the knee joint, at the back of the lower edge of the internal condyle; in other words, at the posterior border of the internal lateral ligament, where it blends with Winslow's ligament, and where the semimembranous tendon is in intimate relation with it. These parts suffer most because, as Mr. Morris says, 'during extension they resist rotation outward of the tibia upon a vertical axis, and a sprained knee is almost always caused by a twist outward of the foot.' 3. For the ankle, on the front of the external malleolus, the apex of the plantar arch, and the tip of the fifth metatarsal bone. 4. For the shoulder, at the point corresponding to the bicipital groove, because in nine cases out of ten a man sprains his shoulder to prevent himself from falling; his hand grasps the nearest support, the body is violently abducted from the arm, the long head of the biceps is called upon to exert its utmost restraining power, the bicipital fascia is overstretched, and the tendon very often misplaced. 5. For the elbow, in front of the tip of the internal condyle; the fan-shaped internal ligament has its apex at that point, and it is most stretched in over-supination with extreme extension of the forearm. 6. For the wrist, the styloid process of the ulna, and the annular ligament in front of the wrist."

The injuries or diseases most likely to give rise to the slight degree of ankylosis which is amenable to the bone-setter's manipulations are rheumatism and gout, displaced tendons or cartilages, sprains, prolonged immobilization during the treatment of fractures, neuromimetic joint affections treated improperly by rest and mechanical support, and ganglions.

The bone-setter's manipulations consist in first locating the painful point, upon which the thumb is firmly pressed during the remainder of the operation; and then, while the operator steadies the proximal segment of the limb, the distal segment is grasped and rotated as much as possible on its axis in order to overcome, as far as may be, muscular resistance, this being accomplished, the joint is sharply flexed or extended in the direction of greatest resistance, and then the reverse movement is made until all the adventitious bands are broken, or until the "bone is put back," in the bone-setter's own phraseology. The rupture of these bands of adhesion is often accompanied by a loud report. For a description of the special manipulations required for each joint, the reader may consult the work of Wharton Hood, above referred to.

It should not be forgotten that most of these stiff joints may be prevented by a proper attention to the treatment of minor injuries of the articulations, and this is one of the principal lessons which we may learn from the bone-setters. If surgeons would never dismiss a case of fracture or sprain until joint motion were perfectly restored, the occupation of the bone-setter would be less lucrative than it now is.

[1] On Bone-Setting (So-Called), and Its Relation to the Treatment of Joints Crippled by Injury, Rheumatism, Inflammation, etc. By Wharton P. Hood, M.D., M.R.C.S., London and New York, 1871

[2] On Some Common Injuries to Limbs: Their Treatment and After-Treatment, Including Bone-Setting (So-Called). By Edward Cotterell, M.R.C.S., Eng., L.R.C.P., Lond., London, 1885.

BONES, TEETH, AND CARTILAGE, CHEMISTRY OF.—The *bones* of vertebrates consist essentially of an organic basis of ossein and the so-called bone earths made up of inorganic salts. Elastin, fat, proteids, and nuclein are also present. Ossein is identical with or very similar to the collagen of connective tissue. In the bone earths calcium predominates in the bases, but small quantities of magnesium are also present and, according to some authors, traces of potassium and sodium. These bases are for the most part in combination with phosphoric acid, but some carbonic acid is found, and traces of chlorine and fluorine. The sulphuric acid mentioned by some writers is probably derived from some of the organic constituents and does not properly belong to the bone earths. There is some difference of opinion as to how the bases and acids are combined, but according to Gabriel the simplest expression for the composition of the ash is $[Ca_3(PO_4)_2 + Ca_5HP_3O_{13} + Aq]$ in which two to three per cent. of the lime is replaced by magnesia potash and soda and four to six per cent. of the phosphoric acid by carbon dioxide, chlorine, and fluorine. As age advances the bones become richer in ash and poorer in water. Hoppe-Seyler gives the following composition for undried bone without separation of marrow or blood: Water, 50 per cent.; fat, 15.75 per cent.; ossein, 12.40 per cent.; bone earths, 21.85 per cent. The composition of the bone earths is given as follows by Zalesky in parts per thousand:

	Man.	Ox.
Calcium phosphate, $Ca_3P_2O_8$	838.9	860.9
Magnesium phosphate, $Mg_3P_2O_8$	10.4	10.2
Calcium combined with CO_2, Fl, and Cl	76.5	73.6
CO_2	57.3	62.0
Chlorine	1.8	2.0
Fluorine	2.3	3.0

Bone marrow is composed chiefly of fat (96 per cent.), containing the fatty acids of ordinary adipose tissue in the proportion of palmitic acid 22, stearic acid 10, and oleic acid 63 per cent. of the total fatty acids. Proteid is present in small quantities, especially in the red marrow of the spongy bones. It is principally in the form of globulin and nucleo-albumin, with traces of albumin. Among the extractives of marrow are lactic acid, hypoxanthin, and cholesterin.

The teeth consist of crusta petrosa, dentine, and enamel. The crusta petrosa is a true bony structure and resembles ordinary bone in composition. Dentine is very similar in composition, but contains less water. Enamel is an epithelial structure containing scarcely any water but rich in lime salts. Its organic constituents differ from the ossein of bone and dentine in not yielding any gelatin on boiling. The following composition is given for the teeth by Hoppe-Seyler from analyses by Aeby:

Constituents.	Dentine.	Enamel.
$Ca_{10}CO_3(PO_4)_6$	72.06	96.00
$MgHPO_4$	.75	1.05
Organic substances	27.70	3.60

Cartilage.—The organic basis of cartilage was formerly known as chondrigen and the gelatin-like substance obtained from it on boiling was known as chondrin; but it is now recognized that the so-called chondrigen is a mixture, containing the following as its chief constituents.

1. Collagen, resembling closely that of connective tissue.
2. An albuminoid substance, resembling elastin but richer in sulphur.
3. A mucin-like substance, known as chondro-mucoid and capable of decomposition into a proteid and chondroitic acid.
4. Chondroitic acid or chondroitin-sulphuric acid, present in combination in chondro-mucoid and also uncombined. Schmiedeberg ascribes to chondroitic acid the formula $C_{18}H_{27}NSO_{17}$.

The inorganic constituents of cartilage are characterized by the abundance of sodium which in adult mammals is principally combined with sulphuric acid. In mammalian embryos and in lower vertebrates the sulphuric acid is largely replaced by chlorine. The composition of cartilage is summarized by Hoppe-Seyler as follows:

In 1,000 parts.	Costal Cartilage.	Articular Cartilage.
Water	676.6	735.9
Solids	323.3	264.1
Organic	301.3	248.7
Inorganic	22.0	15.4

Salts in one hundred parts of ash:

Potassium sulphate	26.66
Sodium sulphate	44.81
Sodium chloride	6.11
Sodium phosphate	8.42
Calcium phosphate	7.88
Magnesium phosphate	4.55

Wesley Mills.
William S. Morrow.

BORAGE.—The leaves and flowering tops of *Borago officinalis* L. (fam. *Boraginaceæ*). A European or Oriental plant, occasionally cultivated in flower gardens in the United States. It has a succulent, branched, hairy stem, half a metre or so high (twenty inches), with rough, coarse-looking, entire leaves, and terminal one-sided cymes of pretty blue flowers. Borage has been a domestic medicine in Europe for years. Its odor is slight, at least when dry; taste, bland and mucilaginous. It contains no more active principles than mucilage and nitrate of potassium, and its medical qualities are only those of a mild demulcent. *W. P. Bolles.*

BORDIGHERA.—A marine health resort on the Mediterranean coast of France, 10 miles east of Mentone and 3 miles west of the Italian boundary.

"Bordighera is a conspicuous object nearly all along the western Riviera, as it is seen glittering in the sunshine, its houses clustered together on a promontory that projects far out into the sea. It is the only health resort on this coast that occupies a position on a promontory; all the others being built round bays or depressions in the coast. It is naturally, therefore, much exposed to winds, that is to say, to all those winds that can reach it in blowing across the sea; the east, the southeast, the southwest, and the west winds can all blow freely upon this promontory. But it is well protected by mountains to the north, northeast, and northwest, whence the coldest winds come. Moreover, it must be remembered that all the winds that reach it must, on account of its position, come to it from the sea, and impregnated with saline emanations. And this is the sole distinguishing characteristic of the climate of Bordighera as compared with that of neighboring stations; the predominating influence of sea air rendering it essentially bracing and tonic" (Burney Yeo).

Bordighera is a small town of 2,500 inhabitants, and the portion devoted to invalids is called the "new town," or English quarter, and is on level ground to the west of the promontory. The hotels and villas are surrounded by groves of olive, lemon, and palm trees. The latter grow to a great height and are said to be more plentiful than in any other part of the Italian Riviera. "It is said that there are more palms in the neighborhood of Bordighera than in the whole of Palestine" (Dean Alford). The natives have a monopoly of supplying the Vatican with palm leaves for Palm Sunday. Dense olive groves also cover the plain upon which the new town is situated. The drainage of the town is primitive, but the place is said to be healthy, and the hygienic conditions are considered good. The water supply is obtained from wells, and from a spring in the flank of Monte Nero (Goodchild). During a residence of fifteen years Dr. Goodchild has seen no case of typhoid fever or diphtheria among the members of the English colony.

The average monthly temperature for the months from October to May inclusive is as follows:

Mean Temperatures, 1876–79.

October	63.5° F.	February	49.1° F.
November	55.0° F.	March	50.5° F.
December	49.0° F.	April	55.1° F.
January	49.6° F.	May	61.0° F.

The temperature averages about three degrees lower than that of Mentone, according to Dr. Goodchild, and the range is smaller. The relative humidity approximates to that at San Remo, which has a yearly average of 66.7 per cent. The rainfall also is about the same as at San Remo, at which place the number of days on which rain falls during the season is thirty. "At Bordighera the mistral is the west wind, being turned completely in that direction by the mass of mountains behind Monaco, and from being forced to blow over the sea it loses somewhat of its dry and cold character" (Burney Yeo). "The soil upon the hillsides is limestone and conglomerate, but upon the flat it is composed of old sandy sea beaches, in which the water rapidly finds the sea level. About a couple of acres near the English church possesses a soil, however, in which there is a small admixture of clay and which is somewhat damp in consequence" (J. A. Goodchild, M.D.).

The climatic characteristics of Bordighera can be summarized as those of a Mediterranean health resort, affording pure sea air, a mild equable winter temperature, a comparatively low relative humidity, and, in common with the other resorts of the Riviera, a large amount of sunshine. Thus, an outdoor life in a mild bracing sea air is afforded. The variety of level shady walks among the palms and olive trees, and the attractive excursions in the neighborhood add a charm and interest to the invalid's life there.

The class of diseases which are likely to be benefited by this climate are those requiring a warm, moderately moist sea climate. As has been said before (*vide* note upon *Algiers*), a climate of this character is not an especially curative one for phthisis, and all that can generally be expected of it in this disease is to ameliorate symptoms and prolong life. Strumous cases, especially in children; patients with anæmia, diabetes, or albuminuria; convalescents from acute diseases; the weak and debilitated; sufferers from chronic bronchial catarrh, from catarrh of the stomach and intestines, and from various other conditions of constitutional feebleness, find here a suitable climate—"cheering to the mind and invigorating to the body."

Bordighera is not suitable for the febrile and for those who are very nervous and sensitive. The accommodations are said to be very comfortable, although somewhat limited. "English tastes are consulted, as nearly all the visitors are English or Americans" (Ball).

Bordighera may be reached viâ Marseilles, or by way of Turin and Savona. By the former route it is thirty-three and a quarter hours distant from London.

Edward O. Otis.

BORIC ACID.—Boric acid (H_3BO_3), often called by the older but less correct name of *boracic acid*, is official in the United States Pharmacopœia under the title *Acidum Boricum*, Boric Acid. It is described as "transparent, colorless scales, of a somewhat pearly lustre, or, when in perfect crystals, six-sided, triclinic plates, slightly unctuous to the touch, odorless, having a faintly bitterish taste, and permanent in the air. Soluble, at 15° C. (59° F.), in 25.6 parts of water, and in 15 parts of alcohol; also soluble in 10 parts of glycerin. Addition of hydrochloric acid increases its solubility in water. An aqueous solution (1 in 50) of boric acid colors blue litmus paper red" (U. S. P.).

Boric acid is a very feeble acid chemically, and physiologically lacks the ordinary acid qualities of sour taste and tendency to irritate. Even a saturated aqueous solution is tasteless, and without irritant action on even so sensitive a part as the conjunctiva. Constitutionally, also, in all ordinary applications, the drug is harmless; but yet poisoning and even death have followed, in a few cases, a very extensive use of the acid. The essential symptoms in such cases were nausea, vomiting, hiccough, feeble heart action, and fall of temperature, with the development of an erythematous rash, affecting particularly the legs.

Boric acid is useful in medicine by reason of its power to arrest the multiplication of microbes. But yet this same power has been overrated. The experiments of Sternberg,* the most precise with which the writer is acquainted, assign to the acid the power of preventing the development of the micrococcus of pus in a one-half per cent. solution; but in the matter of *permanently sterilizing* such organisms—quite another story—the experiments record complete and repeated failure even in saturated (four-per-cent.) aqueous solution, and this not only in the cases of the micrococcus of pus and that of septicæmia, but also in the case of the common *bacterium termo*.

Boric acid, therefore, must be regarded, in the present state of knowledge, as a fairly efficient antiseptic—convenient withal, because odorless, tasteless, unirritating, and non-poisonous in ordinary application—but must *not* be relied upon as a germicide in the proper understanding of the term. Probably because of its antiseptic action, boric acid, locally applied, tends to abate the catarrhal process, and is, for such application, peculiarly agreeable because non-irritating. As a collyrium in conjunctivitis, a gargle in pharyngitis, or an injection in cystitis, solutions of boric acid are, therefore, often efficacious, and at least innocent of harm. For an application to catarrhal surfaces, or for antiseptic purposes to wound surfaces, boric acid may be used in aqueous solution ranging from one to four per cent. in strength—the latter being, indeed, at ordinary temperatures, a saturated solution.

A stronger solution, if wanted, is obtainable by using a mixture of equal parts of boric acid and borax, which dissolves to the extent of sixteen per cent. of water at ordinary temperatures. A convenient and efficient wound dressing may be made by soaking lint in a hot saturated aqueous solution of boric acid, and then allowing it to dry. A boric-acid ointment also has been recommended, where, to a melted mixture of one part each of white wax and spermaceti and six parts of vaseline, is added a proportion of from two to four parts of a saturated solution of boric acid in glycerin. Also the substance *boroglyceride* (see *Boroglyceride*) affords a means of applying boric acid in strong solution. Boric acid has also been given internally in doses of 2 gm. (gr. xxx.) frequently repeated, with no poisonous effect, and with asserted benefit in dyspepsia with fermentation of the ingesta, in chronic cystitis, in diphtheria, and in other diseases probably determined by the multiplication, within the system, of microzymes.

Edward Curtis.

BORLAND MINERAL WELL.—Pleasants County, West Virginia. The well from which the Borland Mineral water flows is situated on the bank of Blue Creek, 6 miles from Salama, on the Ohio River Railroad, and 30 miles northeast of Parkersburg. At present there is no hotel in the vicinity, but nearby farmhouses accommodate a limited number of guests who wish to use the water from the well. The surrounding hills and valleys present some very pleasing landscapes. The water rises from a flowing well, being forced upward by the natural-gas pressure from a depth of three hundred feet. An analysis by Prof. T. G. Wormley, of Philadelphia, showed the following mineral ingredients·

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	240.07
Sodium bicarbonate	112.16
Sodium sulphate	37.84
Magnesium bromide	.28
Potassium sulphate	22.62
Magnesium iodide	.02
Magnesium chloride	2.13
Calcium bicarbonate	12.59
Magnesium bicarbonate	3.12
Aluminum phosphate	.23
Aluminum and iron carbonate	.64
Manganese	Trace.
Silica	.58
Organic matter	Trace.
Total	432.28

Sulphureted hydrogen.................A perceptible quantity.

This water is quite a strong muriated, alkaline saline. It is a very efficient antacid laxative, with diuretic and diaphoretic properties. It also derives a certain tonic and restorative influence from the presence of iron, phosphorus, and manganese. In addition to its table value it has been found to possess excellent therapeutic properties in chronic affections of the stomach, bowels, liver, and kidneys. It acts with great efficacy in renal dropsy.

James K. Crook.

BOROGLYCERIDE.—Under this title there has been introduced into medicine a compound formed by direct reaction of boric acid upon hot glycerin. In this reaction tribasic boric acid replaces the three hydroxyl equivalents of the molecule of glycerin, forming *glyceryl borate*,

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* American Journal of the Medical Sciences, April, 1883.

[illegible]

BORNEOL.—[illegible]

BORRAGINACEÆ.—[illegible]

BORTHWICK MINERAL SPRINGS.—Also known as the Ottawa Mineral Springs.

Post-office.—Ottawa, Canada.

Access.—By carriage drive from Ottawa.

Analysis.—By J. Baker Edwards.

ONE PINT CONTAINS

Solids.	Grains.
Chloride of sodium	[illegible]
Chloride of potassium	[illegible]
Chloride of calcium	[illegible]

[illegible]

BOSTON.—Massachusetts. [illegible]

[illegible]

The cold season begins in November, although it is occasionally mild even to Christmas, and continues until April; snow is for a great part of this time upon the ground, although not always continuously. March, on account of the high cold winds, is one of the most disagreeable months of the year, and June one of the most delightful, although the latter part of the month may be uncomfortably hot. In the summer, the heat, oppressive at times on account of the dampness, is not continuous, and in the writer's experience, from a climatic point of view, the spring and summer are the best seasons to spend in the city, and January, February and March, the months to be avoided by a change to a milder climate. Fashion, however, has it otherwise. The writer recalls the case of a family whose members had come on from St. Louis, in search of an Eastern seaside resort, but who, on arriving in Boston, had found the place so comfortable that they decided to remain there the whole summer.

The excursions by water are numerous and very delightful, and the country around is easily accessible and attractive. Boston is noted for its beautiful suburbs.

Edward O. Otis.

BOSWELL SPRINGS.—Douglas County, Oregon.

Post-Office.—Boswell. Hotel.

Access.—Boswell is a flag station on the Southern Pacific Railroad (Shasta Route), 163 miles south of Portland. The location of the hotel is one hundred feet from the railroad.

The situation is on Elk Creek, about 45 miles from the coast and 350 feet above tide water. The surrounding country is made up of hills and valleys. There are two springs at the resort.

A partial analysis of the stronger spring, made at the University of California, showed the presence of two thousand grains of solid matter to the United States gallon, made up chiefly of the following ingredients: Iron, bromine, potassium, calcium, magnesium, sodium.

The weaker spring was analyzed by Philip Harvey, of Portland, Ore., who gave its contents as follows:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	173.00
Magnesium chloride	145.00
Calcium chloride	115.00
Iron carbonate Calcium	Small quantities.
Total	433.00

Both springs are heavily charged with carbonic acid and sulphureted hydrogen gas. The waters are evidently of the muriated-saline-chalybeate variety. They have been found useful in constipation, chronic malarial infection, dyspepsia, functional liver complaints, and other disorders.

J. K. Crook.

BOTHRIOCEPHALUS LATUS. See *Cestoda.*

BOULDER.—Colorado. A town of 4,000 inhabitants, situated at an elevation of 5,300 feet above sea level, in the heart of the Rocky Mountains, 30 miles northwest from Denver. "The town is situated close to the foot hills near the entrance to the Boulder Cañon" (Solly). The soil is dry and porous, except in areas of clayey soil. The water supply comes from a reservoir on Boulder Creek, five miles above the town, and also from wells, springs, and the creek itself. The hotels are said to be fair (Solly).

Although the meteorological data for Boulder itself are very incomplete, so far as the writer has been able to learn, they cannot be very different from those at Denver, thirty miles away (see article on *Denver*). Solly gives the mean monthly temperature for Boulder, from observations extending over a period of one year and a half, as follows: Winter, 30° F.; spring, 49° F.; summer, 65° F.; autumn is not obtainable. The average number of cloudy days during the winter is 13.

Boulder is one of the many representative places in the great high-altitude, health-resort belt of the Rocky Mountains, extending from Wyoming south along the eastern base of the Rocky Mountains, through Colorado into New Mexico, and then turning southwest into Arizona. "In this belt no particular spot is materially better than another, so far as climatic conditions are concerned" (Report of the Committee on Health Resorts. Transactions of the American Climatological Association, 1895).

Boulder, like many other localities in this belt, would seem to offer an almost ideal climate for the high-altitude treatment of phthisis: almost constant sunshine—but thirteen cloudy days on an average during the winter, clear bracing air, low relative humidity, nights that give invigorating sleep and rest, and grand mountain scenery. But it is well to repeat what has been before said, that climate is but one factor, although an exceedingly important one, in the treatment of phthisis, and in order to obtain the greatest advantage from any climate, however ideal, there must be at hand proper hygienic conditions and wise medical supervision. Phthisical patients in health resorts require, as a rule, constant guidance and restraint; they must know when to practise the *rest cure,* and when it is safe to take exercise and how much.

Edward O. Otis.

BOULDER HOT SPRINGS.—Jefferson County, Montana.

Post-Office.—Boulder. Hotel and cottages.

These springs are located within two miles of the town of Boulder, about midway between Butte and Helena. They are reached by both the Northern Pacific and the Great Northern Railroad. The springs are numerous, and some of them have a large outflow of water. The surrounding country is of a rugged, mountainous character, the location of the springs being 4,904 feet above the sea level. The following analysis, supplied by Mr. George B. Beckwith, manager of the springs, was made at the Columbia School of Mines, New York City:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	4.70
Sodium sulphate	4.30
Sodium carbonate	2.60
Calcium carbonate	1.30
Magnesium carbonate	3.60
Sulphur	4.80
Iron	2.90
Total	24.20

The temperature of the springs ranges from 125° to 187° F. The water is said to be very palatable as a beverage. The hotel is heated by the water of the springs, and bathing facilities are abundant. The diseases especially benefited here are rheumatism, indigestion, chronic constipation, renal, cutaneous, and hepatic diseases, and metallic poisoning.

J. K. Crook.

BOURNEMOUTH, England, is a city of 17,000 or more inhabitants, and is situated on the south coast of England, in Hampshire, 37½ miles from Southampton. "It is built on a flat, pine-covered heath which abuts abruptly on the sea in the form of great brown sandy cliffs." "The East Cliff, the West Cliff, the Valley, and the Coast are the four natural divisions of Bournemouth." The East Cliff, over a great part of its extent, slopes landward and thus has a westerly and southwesterly as well as a southerly aspect; it is the older residential quarter of Bournemouth. The West Cliff is more elevated and exposed than the East, and is the newer part of Bournemouth; it contains the larger number of boarding houses. The Valley of the Bourne affords the maximum of natural protection from the wind which the place can claim. The lower part is an attractive public garden, and the eastern slope, which is covered with pines, affords a perfectly sheltered, sunny and quiet promenade and resting place; the well-known "Invalids' Walk" is to be found here. The Coast is in the form of rugged high cliffs, bright

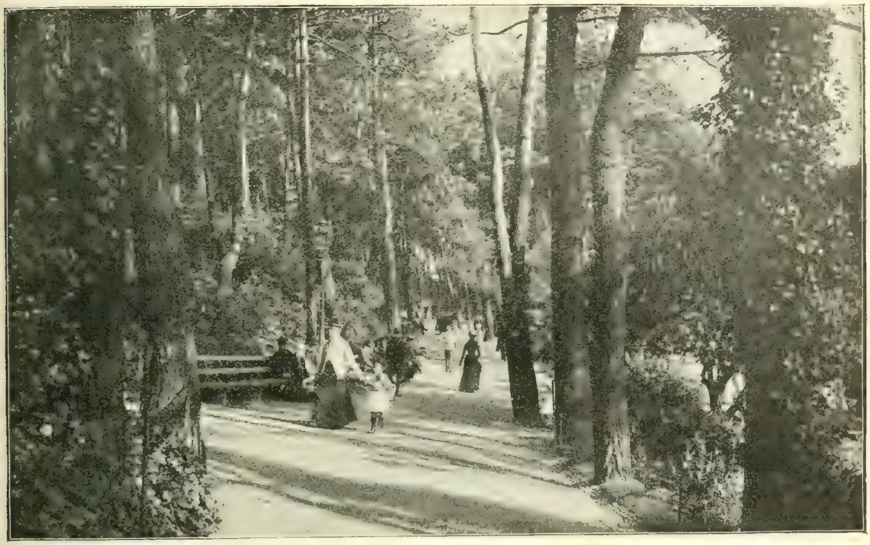

Fig. 679.—Invalids' Walk, Bournemouth, England.

with green and yellow gorse, and broken by deep irregular chines. Pines, much resembling those in our Southern States, are everywhere to be seen. On the East Cliff they are so abundant, fringing the streets and level walks and sheltering the houses, "that this portion of the city has been well described as a town in the wood." The heath all around Bournemouth is also covered with pine woods. The aromatic emanations from the pines are supposed to impart salubrious properties to the atmosphere. Beneath and about the pine trees the furze, rhododendron, and holly flourish in great luxuriance.

The sea lies full to the south, and on the eastern horizon are the Needles and Alum Bay, in the Isle of Wight. A pier 838 feet long extends into the sea and has specially constructed shelters for invalids. The soil, consisting of a greenish sand, is highly absorbent and very dry.

The principal facts relating to the meteorology of Bournemouth are exhibited in the following table:

METEOROLOGICAL MEANS FOR TEN YEARS, 1881-1890.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean temperature (Fahrenheit) at 9 A.M.	40.30°	40.70°	42.80°	49.80°	56.10°	61.50°	64.80°	63.60°	58.80°	51.00°	45.30°	41.00°	51.40°
Mean minimum temperature	34.40	34.50	34.90	38.50	44.60	50.30	54.20	52.60	49.70	42.90	39.80	34.60	42.60
Mean maximum temperature	44.70	45.80	48.50	44.90	62.00	68.20	71.00	70.90	65.80	56.30	51.00	45.00	57.10
Mean relative humidity	85.00	89.00	80.00	68.00	69.00	69.00	69.00	70.00	81.00	81.00	87.00	85.00	77.70
Mean rainfall	2.47	1.85	1.83	1.61	2.13	1.17	2.07	1.84	2.46	3.14	3.36	2.53	27.26
Mean number of rainy days	14.30	10.50	11.50	8.70	10.30	11.30	14.30	15.00	11.50	18.80	17.20	14.70	158.30

From the above we see that the mean temperature for the whole year is 49.7° F., or, at 9 A.M., 51.4° F. The mean minimum temperature is 42.6° F. and the mean maximum 57.1° F. The mean relative humidity at 9 A.M. is 77.7, the lowest recorded in England. The mean total rainfall is 27.26 inches, and the mean number of rainy days 158.3. On an average it has been estimated that there are about two days a week during the winter season when patients cannot go out safely in consequence of rain or occasional cold winds or dust. The town possesses a good drainage system, and the water supply is above suspicion.

The general opinion of local practitioners, as expressed broadly, is that "most cases of pulmonary tuberculosis improve at Bournemouth." At the same time the climate of Bournemouth cannot be represented as equal to the best of the foreign climates, such as the Riviera or the Alpine stations. Dr. C. Theodore Williams' results are: "Twenty patients, each one winter at Bournemouth; six much improved, seven improved, two stationary, and five worse."

The special features of Bournemouth as a health resort, as summarized by the report of a committee of the Royal Medical and Chirurgical Society of London, 1895, to which the writer is indebted for the above account, are as follows:

"Bournemouth is distinguished by the general beauty of its position, which combines the attractions as well as the wholesome influences of sea and heath. As a whole, compared with England, it possesses a mild, bright, and fairly dry climate. The atmosphere is naturally pure, sunny, free from fog, redolent of the pine, of low relative humidity, and comparatively undisturbed by high or cold winds. The soil is dry and warm, permitting patients to sit with comparative safety in the open air; and it supports an abundant and luxuriant growth of non-deciduous trees and shrubs. The town area is very large in relation to the number of houses and inhabitants." On the other hand, "like other places on the south coast, it is subject to frequent and uncertain spells of bad weather, in the form of wet, cold, or both combined, and to even more dangerous, because deceptive, visitations of high east winds in the early spring."

"The kinds of cases which have been benefited by a residence at Bournemouth are chiefly as follows:

"(1) Cases of pulmonary tuberculosis which would do well at any good health resort. (2) Pulmonary tuberculosis in the incipient stage. (3) Quiescent pulmonary tuberculosis when the patient can spend a number of hours continuously in the open air. (4) Patients in the last stage of phthisis often enjoy an extension of life here. In general, cases that can take advantage of outdoor life do well, while those who are confined to the house do badly. (5) Chronic bronchitis without fever, and particularly recurrent bronchial catarrh with a moderate amount of expectoration, asthma, whether neurotic or catarrhal, the different parts of the town being tried if necessary. (6) Chronic Bright's disease, particularly of inflammatory origin. (7) The subjects of chronic malaria. (8) Sufferers from chronic gastric catarrh with emaciation. (9) The victims of nervous over-work, particularly with insomnia, provided they do not settle too close to the sea. (10) Delicate persons generally, including more especially elderly and aged people, and feeble and rickety children."

"The cases, on the other hand, which do not do well or even badly, are: (1) Persons confined to the house, applying chiefly to consumptives. (2) The subjects of pulmonary tuberculosis in its active stage, especially when attended with much fever and profuse expectoration. (3) Those suffering with dry irritable catarrh of the larynx and bronchi. (4) Sufferers from neuralgia."

The accommodations are good and abundant and of every variety. From a personal visit the writer was impressed with the beauty of the place, its clear, bright atmosphere, the abundant sunshine, its luxuriant vegetation, and the striking effect of the great number of pines everywhere. The sea view from the cliffs is most attractive, and there are many pleasing excursions inland over the thickly wooded heath. For an outdoor life one can hardly imagine a more attractive place of residence.

Edward O. Otis.

BOWDEN LITHIA SPRINGS.—Douglas County, Georgia.

Post-Office.—Lithia Springs. Sweetwater Park Hotel.

Access.—Viâ Georgia Pacific Division of the Piedmont Air-Line. These springs are located in Douglas County, 17 miles west of Atlanta, 300 miles distant from the Atlantic coast and at an altitude of 1,200 feet above the sea level. The surrounding country is of a somewhat rugged, broken character, interspersed with forests of pine, oak, maple, and cypress and watered by streams skirted by haw and holly. The temperature rarely reaches 90° F. in summer or extends below 40° above zero in winter, while the nights are proverbially pleasant. The surroundings of the place are exceptionally charming, the Shoals, the Ruined Mill, Chapel Hill, and the Dome Rock, showing the mighty action of some great sea in prehistoric times, the Mill in the Glen, the Old Distillery, and the Sweetwater Creek being also among the numerous features of interest. The hotel is a first-class modern structure, capable of accommodating five hundred guests, and all of the appointments are of a superior order. While people have resorted to these springs for about sixty years, only recently have they become very extensively known.

The use of the Bowden lithia waters is particularly recommended in kidney and bladder affections, calculi, gravel, cystitis, etc., and in gout and rheumatism. The external use of the water in bathing, for which there are excellent facilities, is said to be beneficial in skin affections, chronic ulcers, glandular enlargements, etc. The waters are used commercially, and may be found in most of the principal cities of the East and South.

Following are analyses of the waters:

One United States Gallon Contains:

Solids.	(Upper Spring.) Pratt, 1887.	(Lower Spring.) Pratt, 1889.	Doremus, 1890.
	Grains.	Grains.	Grains.
Carbonic acid as bicarbonates	9.85	......	9.91
Lithium bicarbonate	2.85	1.67	4.45
Potassium bromide	......	5.29	......
Potassium sulphate	......	......	1.73
Potassium bicarbonate	3.36	......	......
Magnesium bromide	1.69	15.23	1.47
Magnesium bicarbonate	10.32	......	......
Magnesium sulphate	4.41	......	......
Magnesium iodide (iodine)	Traces.	.73	Traces.
Calcium bicarbonate	14.18	......	17.25
Calcium sulphate	......	20.21	12.15
Calcium phosphate	.64	......	......
Strontium sulphate	1.02	.28	1.22
Ferrous bicarbonate	.21	......	.21
Sodium sulphate	16.25	......	8.03
Sodium chloride	133.71	124.49	121.78
Sodium phosphate	......	.89	......
Aluminum sulphate	1.33	2.61	.53
Silicic acid (soluble)	1.12	1.96	1.26
Boric acid	......	......	Traces.
Manganese	Traces.	......	Traces.
Phosphoric acid	......	......	......
Rubidium (spectroscopic analysis)	Traces.	......	......
Fluorine	Traces.	......	......
Loss on ignition	......	......	5.75
Total	200.94	173.36	185.74

James K. Crook.

BOW LEG.—(Synonym: Genu Varum.) In the popular sense bow leg includes all the deformities which cause separation of the knees when the ankles are in contact with each other; but, strictly speaking, bow leg implies an outward bending of the tibia and fibula, and genu varum a deformity in which the greatest distortion is at the knee, the opposite of genu valgum. In most instances simple bow leg is associated with slight outward deviation of the knee, and genu varum with a certain degree of bending of the bones of the leg, so that the two terms are properly synonymous.

Etiology.—Bow leg is the most common of all distortions, constituting about ten per cent. of the cases treated in orthopedic clinics. It is essentially a deformity of childhood. It may be congenital, and it is not uncommon in vigorous infants who stand at an early age. But in most instances it is an effect of rachitis, usually of a mild type, and it develops therefore soon after the child begins to walk, although the tendency to deformity may have been acquired before this time. It may be acquired in later life, as an effect of occupation, or injury or disease, but this type is comparatively uncommon.

Symptoms.—The essential symptom of bow legs is the deformity. In the genu varum type, the femur is abducted and rotated outward while the tibia is rotated inward; and in simple bow leg also there may be a spiral inward twist of the tibia, so that in-toeing, "pigeon toe," may be one of the effects of the deformity.

In the more extreme cases, in which there is laxity of the ligaments at the knee joint, the patient may suffer from discomfort and weakness, but this is unusual except during the stage of active rachitis.

Treatment.—There is a strong tendency toward spontaneous recovery, the "outgrowth" of deformity. But although the distortion may be entirely cured by the natural process, it is far more often simply modified and made less noticeable. This may be inferred from the fact that bow leg in the slighter degree is so common in later life. According to the writer's observations, about one adult male in five has noticeable deformity of this character, a proportion that is apparently not exceeded among children. Thus, although bow leg may cause no physical discomfort, it is, from the æsthetic standpoint, of sufficient importance to merit treatment in all cases.

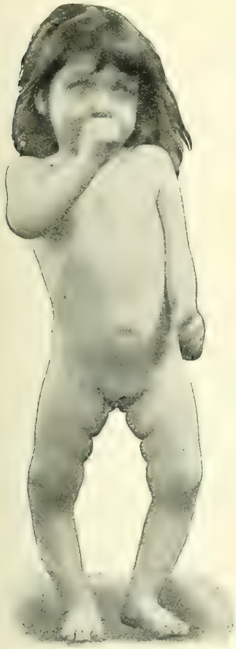

FIG. 660.—Bow Legs of the Genu Varum Type.

It may be easily overcome in infancy by systematic manual correction. It may be prevented in rachitic children by the avoidance of attitudes that induce the deformity, especially standing when the bones are weak. In the slight degree of deformity in walking children, the tendency toward distortion may be counteracted somewhat by making the sole of the shoe slightly thicker on the outer border. If the deformity is more marked, or if it is increasing, or if the bones are abnormally flexible, a brace should be applied. This consists essentially of a light bar of steel, reaching from the internal condyle of the femur to the sole of the shoe. This is suitably padded at the points of pressure and is provided with a laced band which is passed around the limb at the point of greatest deformity, thus supporting it and exercising slight corrective force. If the distortion is most marked at the knee, the bar should be prolonged to the upper third of the thigh, and a second band should be applied about the knee. A jointed brace is less effective than is the simple form that has been described.

The function of a brace is principally support. The correction of the deformity is hastened by daily systematic manual straightening, and cure is accomplished by the natural transformation of the internal structure of the deformed part which begins when the static conditions are changed. In older subjects, when the bones are more unyielding, operative treatment is indicated.

Osteoclasis or osteotomy may be employed. As a rule it is sufficient to straighten the tibia at the point of greatest deformity, but in exceptional cases both the tibia and femur may require treatment. By far the most satisfactory method is partial osteotomy, combined with forcible correction. A small sharp osteotome is inserted directly over the point of greatest deformity on the concave side of the tibia, and when the cortex on its inner surface has been divided the fracture is completed by manual force. The fibula may be bent or broken as it is more or less resistant. In all cases the distortion should be slightly overcorrected, and the limb fixed in this position until union is complete.

Other Varieties of Deformity.—Bow leg may be unilateral, or it may be combined with knock-knee.

Anterior Bow Leg. — Anterior bow leg is a deformity in which the tibia is bowed with the convexity forward. This distortion is usually symptomatic of pronounced rachitis; it is often combined with knock-knee, or with general distortions of the limbs, "corkscrew" deformity. The antero-posterior diameter of the tibia is increased and its crest is prominent and projects sharply beneath the skin. As the weight is thrown upon the anterior part of the foot, the heel projects and the gait is awkward and shuffling. The distortion is not usually amenable to treatment by braces, and in the more extreme cases a cuneiform osteotomy may be required to restore the normal contour.

Royal Whitman.

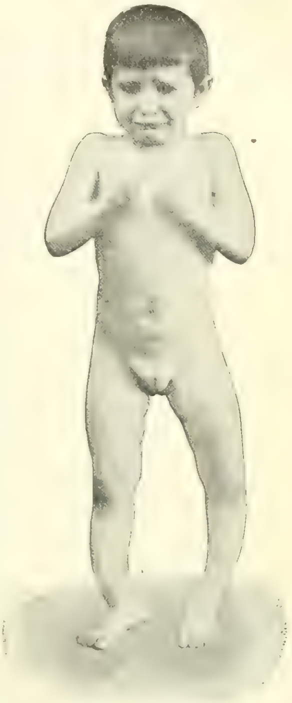

FIG. 661.—Bow Legs in Which the Principal Distortion is Below the Knees.

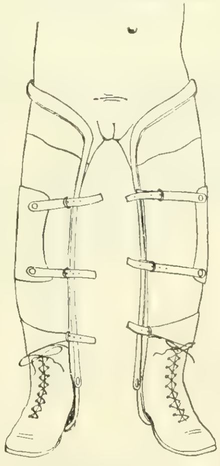

FIG. 662.—Braces for Bow Legs. (Bradford and Lovett.)

BOX.—The leafy twigs of *Buxus sempervirens* L. (fam. *Buxaceæ*). The box is a slow-growing evergreen shrub, rather variable in habit, but usually compact, with a very short trunk, and numerous leafy branches. The leaves are opposite and crowded, 2 or 3 cm. long, elliptical or oval. They are dark green and shining above, pale beneath, thick and leathery. The bark of the younger twigs is green, that of the old trunks gray and tuberculated.

Box is a native of the southern part of Europe and the East. It is frequently cultivated for ornament there, and has been a favorite bordering plant for flower gardens in the United States, where it grows fairly, but very slowly. It seldom blossoms in New England. All parts of the plant are bitter; the leaves and twigs are the most available for medicinal use. By far the most important product of this valuable shrub is its wood, which for many purposes is unequalled.

The bitterness of box is due to the alkaloid *buxine*, discovered by Fauré in 1830. It is a white, amorphous powder of a persistent bitter taste. It is very insoluble in water ($\frac{1}{8000}$), but dissolves rather freely in alcohol, and more freely in chloroform. A second alkaloid, *parabuxin*, was found by Pavia to accompany the buxine in box; and it is still probable that some other principle may be found to explain the poisonous qualities it has been occasionally observed to have.

USES.—Box has had some reputation as a febrifuge and tonic; in large doses it is purgative and emetic. It is suspected of being sometimes used to replace hops in beer; but it is little employed in medicine to-day. The alkaloid *buxine* (bebeerine), either from box or bibiru, has been offered as a substitute for quinine in intermittents, but is much inferior; in the same large doses it deranges the stomach and digestion; in small doses it, however, is an excellent tonic. *Buxine* has been found in several plants of entirely different orders, and is probably, like berberine, a rather extensively distributed alkaloid. The bebeerine of bibiru (*Nectandra Rhodiæi* Schomb.), the pelosine of pareira (*Chondodendron tomentosum* R. et P.), as well as of the false pareira, have been shown by Flückiger and others to be identical with this alkaloid, although it is not quite certain that the physiological effects of buxine from all these sources are the same. The *sulphate* and *hydrochlorate* of buxine are in the market. Dose, as a tonic, from 5 to 10 cgm. (0.05–0.10 = gr. i. ad ij.); as a febrifuge, eight or ten times as much (0.5–1 = gr. viij. ad xvi.).

W. P. Bolles.

BRADFORD MINERAL SPRINGS.—Merrimac County, N. H.

POST-OFFICE.—East Washington. Hotel.

ACCESS.—From Boston viâ the Lowell Railroad to East Washington; thence one mile to hotel at springs. Stages await trains during the season from May 15th to October 15th.

This spring became known to the white settlers in 1770, and since early in the present century its waters have been used for medicinal purposes. An analysis by Dr. Jackson, of Boston, subsequently confirmed by Dr. Richards, of Poughkeepsie, New York, showed the presence of the following ingredients: Sodium chloride, potassium chloride, sodium carbonate, calcium carbonate, magnesium carbonate, calcium phosphate, iron oxide, aluminum oxide, organic matter, sulphur, carbonic acid gas.

We are unable from this analysis to assign the water to its proper class, although it is probably a sulphureted chalybeate. The spring yields twenty-one hundred gallons hourly. The water is clear and sparkling, and emits an odor of sulphureted hydrogen gas. It has been successfully used by the residents of the neighborhood in the treatment of certain cutaneous diseases, especially eczema. It is said to be a very efficient diuretic and tonic, and seems to be well adapted for rheumatism and diseases of the alimentary tract, and for conditions in which the urine is scanty and high-colored. As a douche in nasal catarrh and in catarrhal states of the vagina and uterus it has been found useful. There are bathing facilities for guests who wish to take hot or cold sulphur baths. The surroundings of the place are very attractive, and ample amusements and diversion are afforded the visitor in the way of bowling, shooting, fishing, driving, etc.

James K. Crook.

BRAIN. (ANATOMICAL.)—I. INTRODUCTION. § 1. *Scope of this Article.*—The development of the brain, its growth, histology, functions, blood-vessels and surgery, and the methods of its removal, etc., are presented under appropriate titles. In this article the organ will be considered mainly from the standpoint of normal morphology, with occasional elucidations from embryology, comparative anatomy, and teratology.

I regret that so many points remain undetermined and so many problems unsolved. These relate especially to the meninges and the olfactory region of the brain.

§ 2. *Order of Treatment.*—I. Introduction, §§ 1–13.

II. General Constitution of the Brain, Segments, etc., §§ 14–69.

III. The Metencephal (postoblongata), §§ 70–90.

IV. The Epencephal (preoblongata, cerebellum, and pons), §§ 91–128.

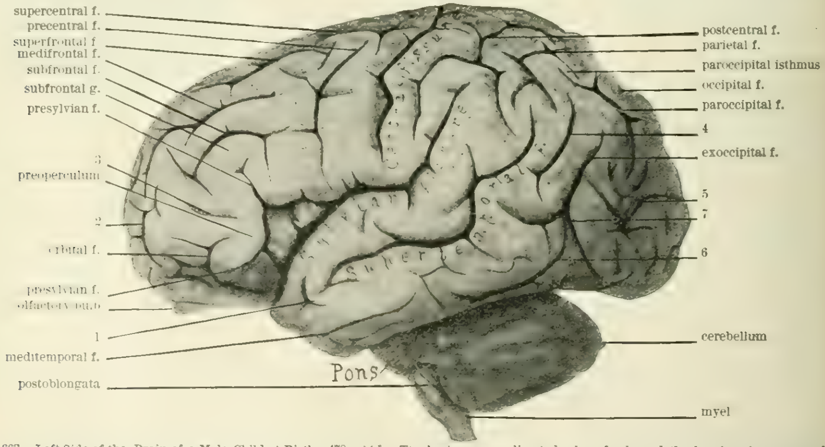

FIG. 663.—Left Side of the Brain of a Male Child at Birth; 478. × 1. The brain was medisected when fresh, and the hemicerebrum spread and flattened considerably while hardening. The specimen is really the right half, but for readier comparison with other specimens and figures a diagram was made (by Mrs. Gage) reversed so as to represent the left half. This figure is based upon a photograph of the diagram. The cerebellum is correct in outline, but no details are shown. Other aspects of the same specimen are shown in Figs. 702, 756, 774, 775. Just ventrad of the narrow isthmus, between the overlapping branches of the subfrontal and precentral fissures, is a white x; 1, 2, 3, 4, 5, 6, undetermined fissures; 7, an isthmus between 6 and the exoccipital which is nearly concealed by the adjoining gyres. See § 4.

V. The Mesencephal (gemina and crura), §§ 129–141.

VI. The Diencephal (thalami), §§ 142–157.

VII. The Prosencephal, its cavities, parietes, commissures, fissures, and gyres, §§ 158–356.

VIII. The Rhinencephal (olfactory bulbs, etc.), §§ 357–372.

IX. The Meninges (dura, arachnoid, pia), §§ 373–409.

X. Bibliography.

§ 3. *Method.*—The text consists largely of commentaries upon the points illustrated by the figures. What seem to me the more important facts and fundamental ideas of encephalic morphology are embodied in concise propositions. Unless otherwise stated these propositions apply to the human brain, and may not always hold good for those of other vertebrates, or even other members of the mammalian class.*

§ 4. *Fig. 663 illustrates:* A. The general aspect of a brain from the side; its continuity with the myel (spinal cord) through the oblongata; the existence of a smaller mass (the cerebellum) and a larger (the cerebrum); the overlapping of the former by the latter more extensive at birth, and in earlier than adult brains; the existence of other parts, the olfactory bulb, the pons, and the oliva (the elliptical elevation of the postoblongata upon which the line from that word ends); the fissures of the cerebrum; the subdivisions of the cerebellum (foliums) are not indicated.

(The remaining points illustrated refer to the cerebral fissures, and may be considered more advantageously in connection with Part VII.)

B. The simple, almost schematic, relations of the fissures demarcating the several operculums (compare Fig. 784); the preoperculum only is named. The suboperculum is the region ventrad of the subsylvian fissure. The operculum is between the presylvian and Sylvian fissures; and the postoperculum is the overlapping margin of the temporal lobe, the region on which is the word *Sylvian* and ventrad of it.

C. The incomplete covering of the insula (see Fig. 788)

D. The presence of a distinct medifrontal fissure, subdividing the medifrontal gyre.

E. The independence of the postcentral, parietal, and paroccipital fissures.

F. The presence of the exoccipital (the "ape fissure" of some writers).

G. The frequency of the zygal or H-shaped form of fissure—*e.g.*, paroccipital, parietal, postcentral, subfrontal, orbital, and fissure 2; see § 307.

§ 5. *The Facts.*—Most of the statements are parts of common anatomical knowledge, and special references are seldom given in this connection; therefore the following extract from the preface to Huxley's "Anatomy of Vertebrated Animals" may be appropriately added:

"The reader, while he is justly entitled to hold me responsible for any errors he may detect, will do well to give me no credit for what may seem original, unless his knowledge is sufficient to render him a competent judge on that head."

§ 6. *The Ideas.*—Unfortunately, the facts of anatomy are susceptible of various interpretations according to the relative weight assigned to them. In particular there are divergent views respecting the segmental constitution of the entire brain and the normal pattern of the cerebral fissures.

§ 7. *The Illustrations.*—Of the one hundred and forty-five figures, one hundred represent preparations made by me for the museum of Cornell University; these preparations are designated by their catalogue numbers. The drawings have been executed, from the specimens and from photographs, by Prof. E. C. Cleaves (C.), Mrs. S. H. Gage (G. or S. P. G.), and Mrs. Wilder. The twenty-five borrowed figures are credited to their sources. The remaining illustrations are original diagrams or drawings, or direct reproductions of photographs.

§ 8. *Terminology.*—The general subject will be discussed in the article *Terminology, Anatomical*, in another volume; meantime those interested are referred to the article under that title in Vol. VIII., of the first edition, pp. 515–537; to "Anatomical Technology" (Wilder and Gage, 1882); to the Reports, during the last ten years, of Committees of the American Association for the Advancement of Science, the American Neurological Association, the Association of American Anatomists, and the Anatomische Gesellschaft; to the article, "Anatomical Nomenclature," by F. H. Gerrish, in "Progressive Medicine," for 1899, pp. 327–346; to G. M. Gould's "Suggestions to Medical Writers," 1900, chap. iv.; and to my address, "Some Misapprehensions as to the Simplified Nomenclature," Assn. Amer. Anat., Proceedings, 1898, pp. 15–39, and *Science*, April 21st, 1899. The principal publications prior to 1896 are included in the bibliography of my "Neural Terms, International and National," *Jour. Comp. Neurology*, December, 1896, vol. vi. Here, therefore, it is necessary only to comment briefly upon the two groups of terms employed in this article.

§ 9. *Terms of Position and Direction* (*Toponyms*).—In place of the more or less ambiguous terms *upper*, *lower*, *anterior*, *posterior*, *inner*, *outer*, etc., will be employed terms referring to the regions of the vertebrate body in whatever attitude it may be—viz., *dorsal*, *ventral*, *cephalic*, *caudal*, *mesal*, *lateral*, *ental*, *ectal*, etc., constituting an intrinsic toponymy. The adverbial forms are *dorsad*, *mesad*, *ectad*, etc.

§ 10. *Terms of Designation* (*Organonyms*).—Each part is designated uniformly by one and the same name. Where two or more names are already in use, the simpler or shorter has been chosen. In some cases simple names have been formed by the omission of unessential words or by the combination of two, or by the coinage of words from the Latin or Greek. Where the English form (paronym) differs from the classical the former is often preferred. For examples, "pneumogastric" becomes *vagus;* "pons Varolii," *pons;* "corpus callosum," *callosum;* "commissura anterior," *precommissure;* "aquæductus Sylvii" and "iter a tertio ad quartum ventriculum" give place to *mesocœlia* (the cavity of the mesencephal), Eng. *mesocele.**

§ 11. *Fig. 664 illustrates:* A. The general form and appearance of the cerebrum of an educated and moral distinguished man, rapid in thought and movement.

B. The general symmetry as to form and especially as to certain fissures, central, occipital, paroccipital, inflected, associated with some decidedly asymmetric conditions—*e.g.*, the relations of the postcentrals to the paracentrals.

C. The bifurcation of the dorsal end of both central fissures and the bifurcation of the caudal branch on each side.

D. The coexistence of the more common relation of the paracentral to the postcentral on the right with the inclusion, on the left, of both branches of the postcentral within the curve of the paracentral; see § 285 and Fig. 769.

E. The great depth of both occipital fissures; this is their real depth, and is not due to a superficial extension.

F. The distinctness and simplicity of the paroccipital fissures, and the existence of the more usual combination —*i.e.*, continuity with the parietal on the left and independence on the right; see Fig. 778.

G. Nevertheless, the difficulty of deciding how this case should be entered upon a Table. On the right the isthmus between the parietal and the paroccipital is perfectly distinct and visible in any direct view; yet it is below the level of the adjacent gyres and might perhaps be regarded as a vadum. On the left the vadum (at the point marked 13) is much more depressed, and hidden from easy view by the overlapping gyre just cephalad of it.

H. The unusual complexity of the fissures representing the parietal and the postcentral. On each side there are recognizable three irregular fissures caudad of the central; the most dorsal of each group is triradiate and perfectly distinct, and is marked *postcentral;* on the right one of the rays (4) cuts the margin of the hemicerebrum deeply. The most ventral (2 and 9) joins the Sylvian fissure. The middle one (3 and 10) is continuous with the parietal on the right, but on the left a vadum may be recognized.

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* The uses of certain animal brains as aids in the study of the human organ are set forth in the article, *Brain: Methods*, etc., and in my paper, 1896, *g*.

* Orthographic discrepancies between this article and my recent papers (*e.g.*, in the retention of certain diphthongs and of the ultima of *anatomical*, *morphological*, etc.) are due to the necessity of conforming to the plan of the entire work.

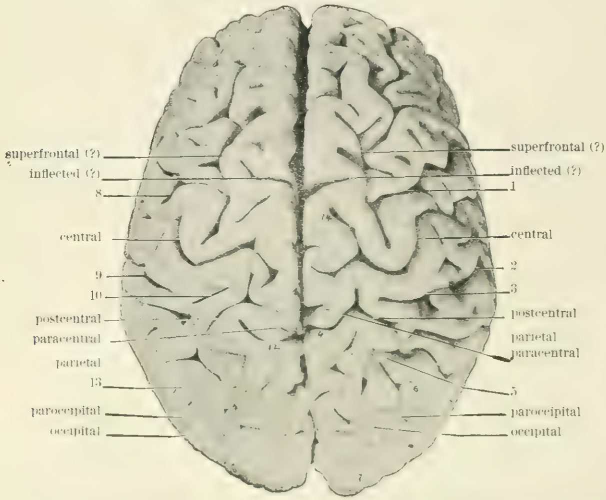

FIG. 664.—Dorsum of the Cerebrum of James Edward Oliver, Professor of Mathematics in Cornell University; aged sixty-six; 3,334. × .57. When removed the brain was firm in texture and weighed (with the piarachnoid but without the dura) 1,416 gm. (49.94 ounces), approximately 50 ounces. It was transected at the mesencephal; the cerebrum was medisected and each half hardened while resting in a mixture of alcohol, formal, zinc chloride and water, of specific gravity equal to that of the brain; later it was transferred to increasing strengths of alcohol. The cerebrum is believed to retain very nearly its natural form. The diacele ("third ventricle") was unusually wide and the medicommissure wholly absent (see § 152). There were no obvious signs of diseased conditions beyond a slight opacity of the piarachnoid about the dorsal ends of both central fissures. Professor Oliver was a man of the purest character and a philosophic thinker, in not only the higher mathematics, but other sciences and ethics. He was left-handed and absent-minded, but rapid in thought and action. For an account of his life and a list of his writings, see the memoir by G. W. Hill, read before the National Academy of Sciences, April, 1896; also *Science*, April, 1895, and the Ithaca *Journal*, March 28th, 1895. 1 (right) and 8 (left), fissures parallel with the centrals and representing, perhaps, both precentrals and supercentrals; they unite with the longitudinal fissures (superfrontals ?); but a vadum exists on each side; 2 (right) and 9 (left), the most ventral of the postcentral groups; 3 and 10, the middle of each group (subcentral ?); 4, a ray of the postcentral cutting the margin of the precuneus; 5, the right paroccipital isthmus; 6, an incision; 7, a distinct diagonal fissure; 8, see 1; 9, see 2; 10, see 3; 12, a fissure cutting the margin of the precuneus deeply but connected with neither the paracentral nor the postcentral; 13, location of the paroccipital vadum. Inadvertently no guide lines indicate the parietal fissures, but they may be recognized from their relations to the paroccipitals. See § 11.

I. The unusual location, depth, and symmetry of the inflected (?) fissures.

§ 12. *References.*—In the Bibliography at the close of this article the names of authors and editors are arranged alphabetically. The date after the name is the year of publication, and the following letter, if there is one, designates a particular paper or book out of two or more published within a single year. My own name is abbreviated in the text to W. My papers on the structure and nomenclature of the brain prior to 1897 are enumerated in the Bibliography of "Neural Terms," 1896, *h*, which is probably accessible to most anatomists either as a reprint or in the *Journal of Comparative Neurology*.

§ 13. *Acknowledgments.*—For assistance in the making of preparations or photographs, for suggestions as to methods, for helpful criticism of the former edition, or for the loan of figures, I am indebted to the following former students, of whom several are present colleagues: P. A. Fish, S. H. Gage, Mrs. Gage, G. S. Hopkins, O. D. Humphrey, B. F. Kingsbury, W. C. Krauss, B. D. Myers, and B. B. Stroud.

II. GENERAL CONSTITUTION OF THE BRAIN.—§ 14. *Definition.*—The *brain* (Gr., ἐγκέφαλος; Lat., *cerebrum;* late Lat., *encephalon;* It., *cervello, cerebro;* Sp., *cérebro;* Fr., *cerveau;* Ger., *Gehirn;* Eng., *encephalon, encephal*) is the enlarged, segmented, cephalic ("anterior") portion of the neuron or cerebro-spinal axis.

§ 15. The neuron* is that one of the great mesal (median) organs which is nearest the dorsal surface of the body, and farthest from the heart (Fig. 665). The other two are the *enteron* (alimentary canal), and the *axon* (skeletal or body axis; notochord in early embryos, but in later stages and adults the series of centrums or bodies of the vertebræ), Fig. 670, *odontoid process*, etc. The enteron is in the ventral (hemal) cavity; the neuron occupies the dorsal (neural or cerebro-spinal) cavity; the axon forms a partition between the two.

§ 16. *Fig. 665 illustrates:* A. The existence, in man as in other vertebrates, of two parallel body cavities, a dorsal or neural, and a ventral or hemal, separated by the axon, the skeletal axis.

B. The presence, in the ventral cavity, of the *heart*, a hollow muscular organ, rhythmically contractile during life.

C. The presence, in the ventral cavity, of a muscular tube, the *enteron* (alimentary canal).

D. The presence, in the dorsal cavity, of a subcylindrical rod, the *neuron* (cerebro-spinal axis), itself containing a cavity, the neurocele ("central canal" and "ventricles").

§ 17. Excepting at its first formation (when it is a rod with a dorsal furrow) the entire neuron is a tube, a subcylindrical mass enclosing a cavity. This cavity is the *neurocele*, and the enclosing material constitutes the celian parietes. The existence of the neurocele may be demonstrated by the transection of any part of the neuron in any other vertebrate, and in an immature human being; but with the adult, in certain regions, the olfactory bulbs (Fig. 672) and most of the myel (spinal cord, Fig. 670), the cavity is more or less completely obliterated.

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* Certain points relating to this word will be discussed in the article *Terminology, Anatomical*. The following brief statement is the abstract of my paper, 1899, *d*, as printed in *Science*, March 16th, 1900, 420: "*Is neuron available as a designation of the central nervous system?* *Neuron* (from τὸ νεῦρον) was proposed by me in this sense in 1884 (*N. Y. Med. Journ.*, August 2d, p. 114), and employed in the same journal, March 28th, 1885, p. 356; in addresses before the Amer. Neurol. Assn. (*Journ. Nerv. and Ment. Dis.*, July, 1885); Amer. Assn. Adv. Sci. Proceedings, 1885, and in the second edition of 'Anatomical Technology,' 1886. It has been employed by McClure, Minot, Waters, and others. The reasons for its abandonment in 1889 for *neuraxis*, as stated in the Proceedings of the Assn. Amer. Anatomists for 1895, p. 44, and REF. HANDBOOK OF MED. SCI., ix., 100, now seem to me inadequate. *Neuron* is the basis of *neural* (as applied to aspect, folds, furrow, and canal) and of *neurenteric* and other compounds, and it is the natural correlative of *enteron* (entire alimentary canal) and of *axon* (notochord or primitive skeletal axis). Not until 1891 did Waldeyer propose *neuron* for the nerve cell and its processes; not until 1893 did Shāfer apply it to the axis-cylinder process. As with *tarsus* and *cilium*, the context would commonly avert confusion between the macroscopic and microscopic significations of the word in a given case. The compounds *macroneuron* and *microneuron* might be employed if necessary, or (as suggested by Barker, 1899, p. 40), the histologic element might be designated by *neurōne*, as if from νευρών. The question is now further complicated by Van Gehuchten's adoption of *Neuráxe* as the title of a new journal of neurology."

§ 18. *Location.*—The brain is contained mainly within the cranium, although part of the postoblongata or even, as appears in Fig. 670, a little of the cerebellum, may extend beyond the limits of the *foramen magnum.* It is remarkably sheltered and clothed by the cranial bones and by the soft parts ectad and entad of them, the scalp and the meninges (dura, arachnoid, and pia) (Figs. 795, 796, 798).

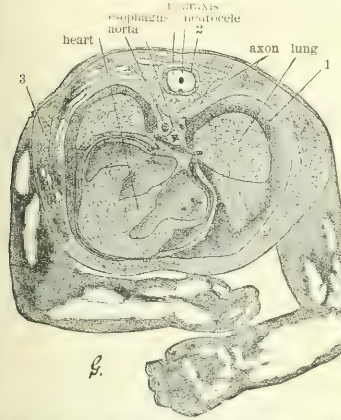

FIG. 665.—Caudal Aspect of a Thoracic Transection of a Fetus About 3.9 cm. from Nates to Bregma, and Estimated at Ten Weeks; 2.139. × 4. 1, Thorax, part of the ventral or hemal cavity; 2, spinal canal, part of the dorsal or neural cavity; 3, scapula.

Defects. The fetus was badly shrunken by immersion in too strong alcohol, and the parts here shown dried somewhat while photographing. Certain details as to the pleura, spinal nerves, and arachnoid are omitted, the object of the figure being mainly diagrammatic. See § 16.

§ 19. *The Brain a Modified Tube.*—In its simplest expression the brain, like the remainder of the neuron, may be represented as a tube of nervous tissue lined by a nonvascular, ciliated* epithelium, the endyma ("ependyma"), and covered by a vascular membrane, the pia ("pia mater").

§ 20. In what may be regarded as an approximately typical condition, the parietes consist of three layers or strata, viz., an ental, mainly cellular, adjoining the endyma, the *entocinerea* ("central tubular gray"); an ectal, mainly cellular, adjoining the pia, the *ectocinerea* (cortex); an intermediate, fibrous, between the other two, the *alba* or medulla; see Fig. 666. In some regions, particularly the epicelian and paracelian roofs, the entocinerea is dislocated or crowded as it were from its normal position next the endyma by albal or fibrous intrusions, commissures, especially the callosum. Parts of the ectocinerea (*e.g.*, claustrum and lenticula, Fig. 781) are also separated more or less completely from the rest.

§ 21. *Unequal Thickness of the Parietes.*—In the earliest stages the celian parietes are of approximately equal thickness throughout, although certain portions of the roof, *e.g.*, of the metacele, are never so thick as portions of the floor. With some low or generalized vertebrates —*e.g.*, *Scymnus*, a shark (T. J. Parker); *Necturus*, a salamander (W., 1884, *a*, Fig. 16); *Ceratodus*, a Dipnoan (W., 1887, *a*)—this condition prevails throughout life, at least with certain regions.

With man, until the fetus attains a length of at least 6 cm., and an estimated age of twelve weeks (see Fig. 667), the cerebral parietes are almost uniformly thin; when 24 cm. long, and about twenty weeks old, certain regions are considerably thicker than others, as seen in Fig. 716; in the adult brain of man, and indeed of mammals generally (Figs. 686 and 735), the difference between even closely adjacent portions of the parietes is simply enormous; compare, *e.g.*, the mesencephalic floor (crura) with the caudal part of its roof, valvula (Figs. 670 and 687); the two divisions of the epicelian roof, cerebellum and lingula (Figs. 670, 687, 702); the diacelian sides, thalami, with the floor, tuber or terma (Figs. 670 and 687); the thin or membranous parts (fimbria, tenia, pala, etc.) adjoining the rima with the adjoining hippocamp and caudatum (Figs. 716 and 732).

§ 22. *Telas.*—Where the proper nervous constituent of the parietes is wanting the endyma and the pia are in contact and constitute a membranous area or zone, a tela. Among vertebrates the most constant and extensive of these is the roof of the metacele, the caudal portion of the "fourth ventricle," here called metatela (Figs. 675, 680, 686).

A similar portion of the roof of the "third ventricle" is the diatela (Figs. 675, 681, 682); its cephalic continuation as the roof of the aula is the autatela; finally, in man and apes, a part of the floor of the paracele ("lateral ventricle") is a membranous zone, the paratela (Figs. 733, 735).

§ 23. *Fig. 667 illustrates:* A.—The large size of the paracele, the thinness of the parietes and their nearly uniform thickness.

B. The extent of the paraplexus, and its fulness as compared with that in the adult. Possibly when fresh it more nearly filled the paracele, but was contracted by the alcohol (compare Figs. 716 and 735).

C. The similarity of the precornu and medicornu.

D. The absence of distinct indication of the postcornu, indicating that this may be formed eventually not by a special protrusion caudad, but by the thickening of the

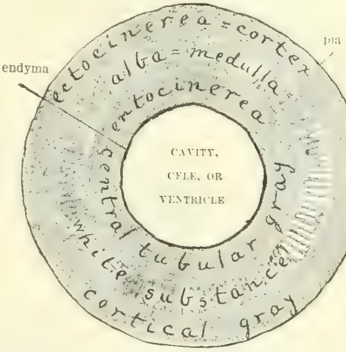

FIG. 666.—Schematic Transection of the Brain, representing the topographical relations of the two kinds of nervous substance, the white, which is fibrous and conducting, and the gray, which is cellular as well as fibrous, and dynamic in function. The entocinerea is primary, and alone exists in the myel; the ectocinerea is secondary; it constitutes the mesencephalic cappa, and the cortex of the cerebrum and cerebellum. The cilia are omitted.

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* There is considerable divergence of statement among authors as to the presence of cilia, especially in adults. P. A. Fish has described (1890, 256) the ciliated cells in the encephalic cavities of the cat, both old and young. He urges the importance of thorough preservation by the injection of the preservative into the cavities; states that a magnification of not less than six hundred diameters must be employed, and intimates that the failure to recognize them in man may be due to defective methods of preparation or examination. See also the recent paper of Studnička: "Ueber das Ependym des Centralnervensystems Wirbeltiere," *Sitzungsber. K. Böhm. Ges. Wiss.*, Math. Nat. Cl., 1899, xlv., p. 7.

parietes in such a way as to leave an occipital space of variable size.

E. The commencing formation of the hippocamp as a corrugation of the mesal wall of the medicornu.

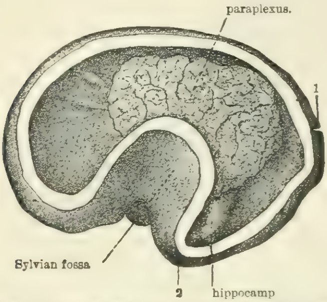


FIG. 667.—The Left Hemicerebrum of a Fetus (Measuring 6 cm. from Bregma to Heel, and Estimated at Twelve Weeks), Opened from the Lateral Aspect; 340. × 3. 1, A fissure; 2, tip of temporal lobe.

F. The non-extension of the paraplexus and thus of the rima to the extremity of the medicornu.

G. The presence of at least one distinct transitory fissure (1).

H. The evidences of some mesal fissures as slight corrugations just cephalad of the plexus.

I. The formation of the Sylvian fossa, with as yet no trace of the insula.

§ 24. *Plexuses.*—As already stated the endyma is nonvascular; but provision is made for the practical introduction of blood-vessels into the encephalic cavities by the formation of plexuses at various points. A plexus is an apparent intrusion of a fold of pia, or of vessels from the pia, into one of the cavities; but the endyma is carried before the intruded portion, and covers it completely so that, strictly speaking, neither the pia nor its vessels are in the cavity. The conditions are comparable with the relations of the abdominal viscera to the peritoneum. If one takes a closed sack of flexible material and pushes the fist against one side it may be carried so far as apparently to be within the sack; yet all the while it is covered by the material of the sack and strictly excluded from the true cavity. Simple examples of the plexus formation are presented by the epiplexus (Fig. 695), and portiplexus (Fig. 668). The metaplexus is seen in Fig. 686; the diaplexus in Figs. 686 and 732; and the paraplexus in Figs. 718, 726, and 732. The disproportionate size of the paraplexus at early stages (Figs. 667 and 747) indicates that it is intimately related to the growth of the cerebrum. The structure and diseases of the paraplexuses are discussed by Findlay, 1889.

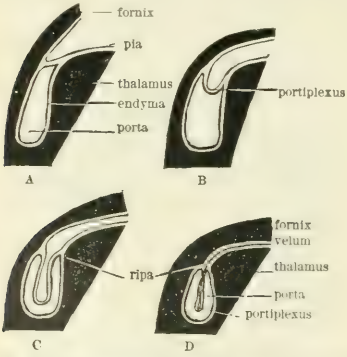


FIG. 668.—Schematic Representations of Four Stages in the Formation of the Portiplexus, as a Type of Plexuses. At A the porta is seen to have the following boundaries: cephalad, the fornix; caudad, the thalamus: ventrad, the junction of the two; dorsad, however, there is merely the endyma passing from fornix to thalamus, and the ectal pial fold, one of its laminæ being fornical and the other thalamic. The first step in the formation of any entocelian plexus is represented at B, where the pial fold (or vessels therefrom) pushes the endyma before it into the cavity. At C the process is carried a step farther, and at D the parts are represented as in the adult, with the plexus apparently inside the porta, and yet really excluded from the cavity by the unbroken covering of endyma.

§ 25. *Ripa.*—Where the endyma leaves the nervous parietes either at the margin of a tela or for reflexion upon a plexus, there is a sort of shore line which I have called ripa. The name was originally given to the ragged edge left when a tela or plexus is torn from the nervous parietes (see Figs. 692, 699).

§ 26. *Fig. 669 illustrates:* A. The effect of the cranial flexure (§ 36), the two segments, mesencephal and epencephal, with their cavities, appearing upon the same section surface.

B. The triplicity of the epicele, consisting as it does of a mesal portion and two lateral extensions, the lateral recesses (§ 60). In Fig. 695 the lower part of the figure is still more enlarged, and commented upon.

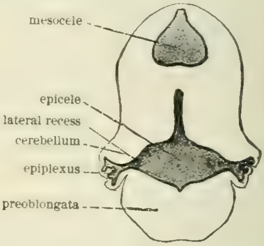


FIG. 669.—Transection of the Brain of an Embryo Rabbit, Sixteen Days Old. × 9. (From Kölliker.)

§ 27. *The Brain as a House.*—Within certain limits the brain may be likened to an edifice, and the comparison has been carried out in some detail on p. 413 of Wilder and Gage, 1882. Architectural terms, *floor, roof, sides*, may be employed appropriately to indicate the general locations of the parts relatively to each other and to the common cavity, and I have proposed two specific terms, *aula* (a hall) and *porta* (a doorway), for the designation of certain portions of the cavity.

§ 28. *Irregularities of Contour.*—In the brain straight lines and plane surfaces are infrequent, and the spiral form is not uncommon; hence dissections are often more instructive than mechanical sections, and normalization, actual or ideal (§ 38), is sometimes desirable.

§ 29. *Commissures, etc.*—Of the parts connecting lateral masses across the meson, whether cellular or fibrous, whether direct (true commissures) or oblique (decussations), some are merely specializations of pre-existing floors or roofs; *e.g.*, precommissure, postcommissure, supracommissure, pons; others, the callosum and commissure of the fornix, are marked extensions of pre-existing lines or areas of conjunction (Fig. 741). The medicommissure, finally, as well remarked by Spitzka, is rather a fusion of contiguous surfaces than a commissure in the usual sense of the word.

§ 30. *Atrophic Parts.*—Certain parts (terma, hemiseptum, valvula, tuber) which are very thin and apparently functionless, nevertheless serve to contain the neurolymph (cerebrospinal liquid), and may have a morphological significance as representing parts more developed in other forms. Two other parts, the epiphysis ("pineal body") and the hypophysis ("pituitary body") are rather thick than thin, but are not known to have definite functions; their peculiarities will be considered in connection with the diencephal (§§ 146, 154), of which they are appendages.

§ 31. *Riparian Parts.*—Along the ripas, or lines of reflection of the endyma upon telas or plexuses, the substantial nervous parietes are commonly reduced in thickness, so as to resemble the terma, valvula, and tuber in some degree. Such are the obex at the end of the metacele (Fig. 702); the fimbria along the hippocampal margin of the rima, the tenia along its caudatal margin, and the pala at its extremity (Figs. 730, 732, and 735).

§ 32. The riparian condition may not be incompatible

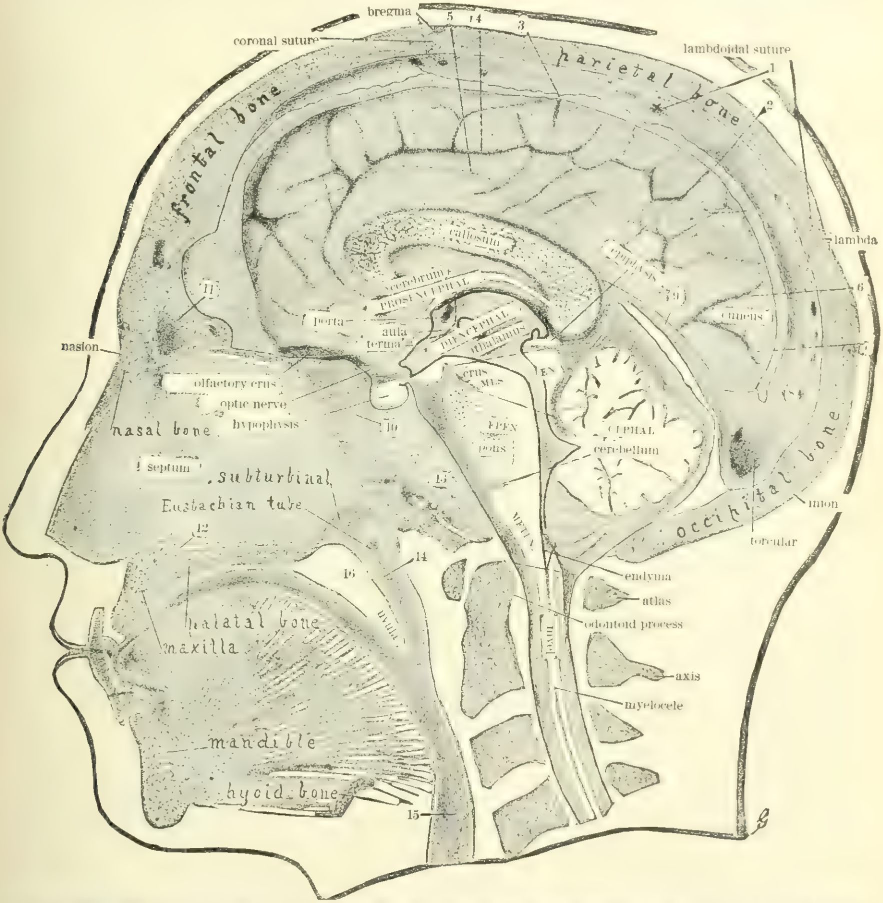


FIG. 670.—Mesal Aspect of the Right Half of an Adult Head, the brain hardened in place by continuous alinjection; §11. × .7. (This was the head of William Menken, who was hanged for murder in July, 1885; the specimen was shown at the American Neurological Association in 1886, and at the American Laryngological Association in 1888 [see article by Dr. Harrison Allen, in *New York Medical Journal*, February 2, 1889]; the mode of preparation is described in the article *Brain: Methods*, etc.). 1, The star upon the mouth of a vein opening into the longitudinal sinus indicates the location of the dorsal end of the central fissure; 2, caudal part of the paracentral fissure; 3, inflected fissure; 4, supercallosal fissure; 5, callosal margin of the falx, indicated by the interrupted line; 6, occipital fissure; 7, calcarine fissure; 8, in the longitudinal sinus just dorsad of the torcular; 9, tentorial sinus; 10, a sphenoidal sinus (not vascular, but a cavity in the sphenoid bone); 11, a frontal sinus; 12, naso-palatine canal; 13, basioccipital bone; the basisphenoid has 10 upon it, but the two bones are continuous: 14, naso-pharynx; 15, oro-pharynx; 16, soft palate. The heavy black line bounding the shaded mesal cavities is the endyma.

Defects.—The planes of section of the brain and of the other parts are not absolutely identical, although perhaps nearly enough so for most purposes. Many of the boundary lines are too faintly indicated, *e.g.*, that of the section of the chiasma. A continuous line representing the pia should have surrounded all the cut surfaces in close contact therewith. Another line representing the arachnoid should follow the general contours, as stated more fully in connection with Fig. 801. The segmental name *diencephal*, hides most of the oval area indicating the medicommissure; this last should have been named and should not be dotted. The heavy black line representing the endyma should extend farther into the stem (infundibulum) of the hypophysis, and into the epiphysis, as in Fig. 687. At the second E of the abbreviation MESEN the endymal line should not be interrupted. The interruption opposite the *n* of the abbreviation METEN represents the metapore (foramen of Magendie), and should have been so designated as in Fig. 687. Notwithstanding the minuteness of the myelocele ("central canal of the cord") in the human adult its location should have been indicated by the continuation of the endymal line. The neck, scalp, features, and all the soft, vascular parts are swollen by the alinjection; the margins of the tongue are moulded upon the teeth; the soft palate and dorsal wall of the pharynx are obviously thickened, and the subturbinal projects beyond the true margin of the septum into the naso-pharynx, as is perhaps the case temporarily during the congestion attending a severe "cold in the head." No attempt has been made to indicate the blood-vessels, the structure of the skin, the exact direction of the lingual muscles, or the details of the nuchal region.

with distinct and even important functions. The supracommissure and the habena (Fig. 707), for example, are, in one sense, parts of transition from substantial to membranous parietes; but they doubtless, like the fimbria, have some distinct use.

§ 33. *Marginal Cinerea.*—The riparian parts mentioned in § 31 consist of alba; but with the cerebrum and cerebellum the cortical margins have a special morphological interest, and are but little known.

§ 34. Physiologically the intermediate portions of organs are commonly most important, as well as most easily recognized and examined; but morphologically the extremes have great significance, and present unsolved problems for future investigators.

§ 35. *Fig. 670 illustrates:* A. The relative location and extent of the cranial and facial regions of the head so far as they appear at the meson.

B. The continuity of the two portions of the neuron, the myel ("spinal cord"), and the brain (encephal), at or near the junction of the cranium with the spine.

C. The obvious subdivision of the brain into several regions, represented, for example, by the cerebellum, the cerebrum, and the intervening narrower part, which is sometimes called *isthmus cerebri.*

D. The possibility of recognizing in the adult brain smaller divisions or definitive segments, corresponding with the divisions of more nearly equal size in certain other vertebrates.

E. The difficulty of assigning exact limits to the brain and myel or to the regions of the brain, since they are continuous and do not present arthra (articulations or joints) as with the skeletal segments.

F. The representation of each segment at or near the meson by some well-known part: the metencephal by the postoblongata; the epencephal by the cerebellum and pons; the mesencephal by the crura and geminal lobes; the diencephal by the thalami; the prosencephal by the cerebrum; and the rhinencephal by the olfactory bulbs.

G. The existence of a mesal series of communicating cavities surrounded by the endyma.

H. The insignificance of the aula, the mesal cavity of the prosencephal, as compared with not only the other cavities but the cerebrum itself.

I. The presence of an orifice, the porta ("foramen of Monro"), evidently leading laterad from the mesal aula into a cavity within the right hemicerebrum.

J. The relations of the masses to the cavities, as are related the floors, roofs, and side walls of an edifice to the apartments.

K. The great difference in the thickness of the roofs and floors at different points.

L. The continuity of the side walls, floors, and (excepting at one point) of the roofs.

M. The existence of certain fibrous masses, commissures, extending across the meson, and therefore divided in this preparation.

N. The lodgment of a subspherical appendage of the base of the brain (the hypophysis) in a deep pit in the floor of the cranium (the "pituitary" or hypophysial fossa).

O. The change in direction of the cranial floor at about this point, the remnant of the embryonic cranial flexure.

P. The similar angle formed by the base of the brain.

Q. The still more decided angle formed by the general outlines of the floors of the encephalic cavities at a point nearly corresponding with the cephalic orifice of the mesencephalic cavity.

R. The liability of misapprehension from the employment of the ordinary descriptive terms, *vertical, horizontal, anterior, posterior, upper,* and *lower,* since each of these words would have one meaning for the myel and postoblongata, and another for the diencephal. It is as if two adjoining houses faced, one to the east and the other to the south. The employment of *eastern* and *southern* as designating structural features common to the two would be likely to cause misapprehension.

S. The convenience of regarding the entire floor as ventral, the entire roof as dorsal, any region of the brain nearer the myel as relatively caudal, and any region farther therefrom as relatively cephalic.

T. The dorsal expansion of most of the segments. The wedge-like shape of the mesencephal is easily recognized; the thalami are not wholly exposed, but the region is more extended dorsally than ventrally; the cerebellum is much larger than the pons, while the disproportion of the cerebral hemispheres to their strictly basal, mesal part, the aula, is one of the many remarkable features of the adult human brain.

U. The tendency of certain segments to overlap adjoining parts, especially in the caudal direction.

V. The lack of exact collocation between the encephalic regions and the cranial bones; the cerebellum corresponds to less than half of the superoccipital bone, and extends a little beyond its margin at the *foramen magnum.*

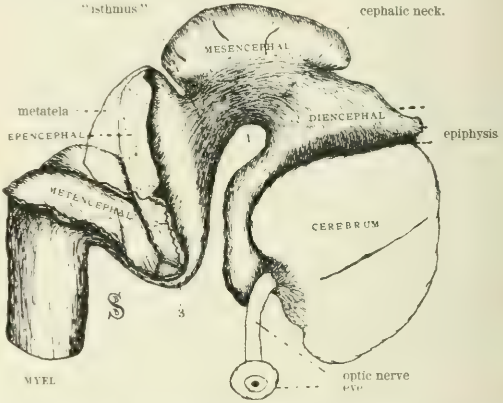


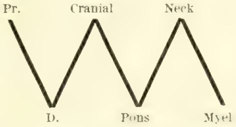
FIG. 671.—Right Side of the Brain of an Embryo 22 mm. Long and Estimated at Eight Weeks; 2.652. × 7. Prepared and drawn by B. B. Stroud (1899, *a*). 1, Cranial flexure; 2, torn edge of the metatela; 3, pons flexure. The olfactory bulbs are not shown. See § 37.

W. The collocation of the lambdoidal suture with the dorsal end of the occipital fissure.

X. The location of the mesal craniometric points, nasion, bregma, lambda, and inion.

§ 36. *The Encephalic Flexures.*—These are commonly described as three, the *cranial,* the *pons,* and the *neck.* The second and third are temporary in man, respectively indicating the junction of the myel with the postoblongata and of the latter with the preoblongata. The cranial or mesencephalic flexure is a permanent feature of the human brain, as seen in Figs. 670 and 687. There is, in addition, a flexure, likewise permanent, in the diencephal so that the prosencephal is dorsad instead of cephalad of it; this persists in man and other Mammals, and in Birds and Reptiles, but with Amphibia and "fishes" the prosocele and diacele are on approximately the same level; see my papers, 1887, *b,* and 1896, *d.*

The relative positions of the several encephalic flexures, although not their relative sharpness or the length of the intervening parts of the brain, may be indicated to the eye approximately by a capital **W**, with an oblique line (half of a **V**) for the myel. In the accompanying diagram the three flexures commonly named are indicated by the words cranial, pons, and neck; Pr. stands for the prosencephalic region, and D. for the diencephalic flexure. In this diagram, in accordance with my custom, the cephalic ("anterior") end is at the left. Unfortunately, however, the two figures which illustrate the flexures most perfectly (671 and 676) have the reversed position, so that comparison with the diagram is less readily made.



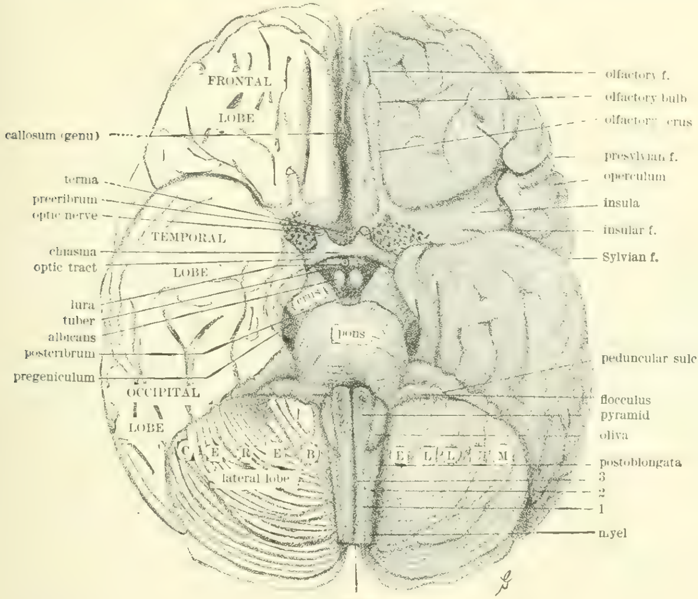


FIG. 672.—Base (Ventral Aspect) of the Brain. From Henle, Edinger, and nature. × .7. 1, Ventral ("anterior") column; 2, line between the ventral and lateral column; 3, ventrimesal fissure.

Preparation.—The cerebellum has been allowed to fall dorsad by its own weight; thereby the occipital lobes are divaricated somewhat, the encephalic curvature is reduced, and the crura are more fully exposed. The hypophysis and infundibulum have been severed from the tuber, and the pia removed, together with the cranial nerve roots, excepting the optic. The right olfactory crus has been divided near its attachment. On the left the operculums are divaricated somewhat, so as to expose the ventro-lateral aspect of the insula.

Defects.—As may be seen from profile views of the brain (Figs. 670 and 687), in the normal condition of the organ the pons and the chiasma are naturally nearly in contact, and the intervening regions, crura, etc., are practically invisible; the ventral surface of the metepencephal also forms little more than a right angle with that of the prosodiencephal; consequently in a direct view of either region the other is greatly foreshortened, and even the equal division of the obliquity between them shows neither to advantage. The fresh or imperfectly preserved brain, when resting upon the dorsal aspect, will, however, straighten itself, as it is commonly represented. To include so large a surface within a figure of moderate size certain details must be inadequately presented or omitted altogether. The fissures in the present figure, substantially as given by Henle, need not be regarded as signifying anything more than the general aspect of the cerebrum. The two crura should be equal in width. The pyramid decussation is inadequately indicated (see Fig. 689). See § 41.

§ 37. *Fig. 671 illustrates:* A. The general form of the brain at this stage, especially the sharpness of the several flexures.

B. The size and prominence of the mesencephal and its extension over the adjoining regions.

C. The distinctness of the constriction cephalad of the mesencephal as compared with that caudad, and the apparent absence of reason why the latter should be regarded as a definitive segment any more than the former.

D. The presence of corrugations on both the mesencephal and the cerebrum. The former appear in many of our preparations; the latter may be artifacts.

§ 38. *Normalization.*—This term is used to include all processes by which modified or morphologically abnormal forms and relations may be reduced, either actually or ideally, to their known primitive and presumed normal conditions. *Rectification* would have nearly the same significance; it denotes the reduction of complex structures to simple, of irregular to regular, of crooked to straight, and of rough to plain. Examples of this process are the representation of the segments as subequal in size and on the same plane (Figs. 674 and 675); the lateral extension of the various outgrowths of the mesal parts (Figs. 683 and 714); the straightening of the medicornu (Fig. 729); the schematic representation of the fissures (Figs. 757 and 758), and the designation of the human geniculums as pre and post rather than external and internal (§ 62, K).

§ 39. *The Brain a Segmented Organ.*—A fundamental morphological idea * of the brain is that it consists of a *series of segments*, comparable, although not, probably, strictly equivalent. The development and comparative anatomy of the organ can hardly be treated upon any other basis; it is recognized in the discussion of encephalic physiology and of psychology, and the descriptive anatomy of the organ is most conveniently based thereon.

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* Like other symmetrical organs it consists of right and left halves, approximately identical. It is also regarded by some as divisible into dorsal and ventral zones; but this has not, I think, been demonstrated for the entire brain.

§ 40. The segmental constitution of the human brain is invisible from the dorsal aspect (Fig. 664); hardly suggested when the cerebellum as well as the cerebrum is in view; more obvious from the lateral aspect (Fig. 663); still more so from the ventral side (Fig. 672); clearer still from the mesal aspect (Figs. 670, 687, and 756), and unmistakable with early embryos (Figs. 671, 673, and 679), which therefore, but for practical difficulties as to procuring, preserving, and dissecting, would form a natural introduction to human encephalic morphology.

§ 41. *Fig. 672 illustrates:* A. The enormous preponderance of the visible parts of the prosencephal and epencephal over the other segments, thereby occasioning the common and not unnatural though very unphilosophical division of the entire brain into cerebrum (cerebrum proper, olfactory bulbs, and thalami) and cerebellum (with pons and postoblongata), the intervening narrow region, the crura and the quadrigeminum, being regarded as merely an isthmus.* From the morphological standpoint, however, the statement would be nearly reversed. The mesencephal is at one period the most prominent and distinct region (Figs. 671 and 676). The cerebellum may be characterized as an hypertrophied bridge over the "fourth ventricle," and there are some grounds for regarding the olfactory bulbs as primary, and the cerebral hemispheres as their secondary appendages (see my paper, 1887, *a*).

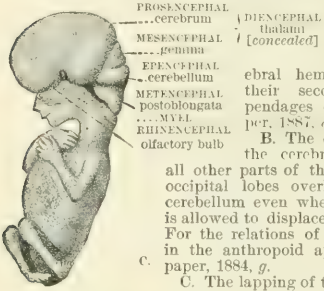

FIG. 673.—Fetus Measuring 49 mm. from Nates to Bregma, and Estimated at Twelve Weeks; 1828. × 1. The specimen was received in alcohol, still enclosed by the membranes. After removal it was pinned to loaded cork and kept under alcohol during the exposure of the brain. The attitude and expression are noteworthy, and have been faithfully reproduced by the photograph and drawing; the right side of the brain is shown in Fig. 746, and the dorsal aspect was published in the *New York Medical Journal*, February 16th, 1884, p. 177.

B. The extension of the cerebrum beyond all other parts of the brain, the occipital lobes overlapping the cerebellum even when the latter is allowed to displace the former. For the relations of these parts in the anthropoid apes, see my paper, 1884, *g*.

C. The lapping of the temporal lobe over the optic tract, as shown by the two interrupted, curved lines on the right (left of the figure). .

§ 42. *Fig. 673 illustrates:* A. The general form of the body and limbs at this period.

B. The visibility of all the encephalic segments, excepting the diencephal; even this may be regarded as represented by the optic nerve, dimly seen through the indentation at the ventral margin of the cerebrum.

C. The marked preponderance of the cerebrum.

D. The absence of the transitory fissures; compare, however, the right hemicerebrum, as shown in Fig. 746.

E. The simplicity of the other regions, better shown in Fig. 746; the cerebellum is a narrow and undivided mass; the mesencephal presents a slight transverse depression between the pregeminum and postgeminum.

§ 43. The recognition of the brain as a segmented organ is not dependent upon the determination of the exact number of segments, their equivalency, or their boundaries. The postoblongata represents several *potential* segments or neuromeres, but practically it may be regarded as one. Some even regard the entire oblongata together with the cerebellum and pons as a single segment.

§ 44. Some idea of the diversity of opinion and usage among anatomists with respect to the number and designations of the definitive segments may be gained from the table published in the first edition of this work (viii., 114), which is substantially the same as in my paper, 1885, *b*, and in Wilder and Gage, 1882, 405. The appended Table I. indicates the difference between the verbal schemas adopted by the Anatomische Gesellschaft in 1895, and by the Association of American Anatomists in 1897; the second is followed in the present article.

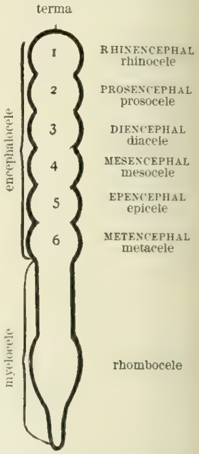

FIG. 674.—Schema of the Neuron (Cerebro-Spinal Axis), as if the cavity were exposed by the removal of the roof. The six encephalic segments are given a conventional spherical form, but without intending to imply that this is their actual shape or that all are separated by constrictions. The main object of the diagram is to associate the encephalic segments with their names and the names of their cavities.

§ 45. *Commentaries on the Schematic Medisected Brain, Fig. 675.*—A. No two original workers in comparative neurology would be likely to construct schemas identical in all respects; the one here presented is not satisfactory to me and I can hardly expect it to suit others. But with all its defects I believe it may serve three useful ends—viz.: (*a*) indicate the relative position of certain parts in the floor or the roof of the general cavity; (*b*) facilitate the recognition of the essential identity of the brains of all vertebrates with that of man; (*c*) stimulate efforts toward the construction of a more perfect schema.

B. Only mesal parts are presented, *i.e.*, such as are divided in a medisection.* This excludes the cerebral hemispheres and olfactory bulbs, the lateral lobes of the cerebellum, and the elevations of the crura and quadrigeminum at the side of the ventral and dorsal mesal furrows.

C. The parietes present four degrees of thickness, viz.: (*a*) thin, *e.g.*, the terma and the tuber in the floor, and in the roof the valvula and the lingula between the thickened quadrigeminum and cerebellum; (*b*) thick, *e.g.*, the two just mentioned, the crura, and the oblongata caudad of the pons; (*c*) reinforced, *e.g.*, the pons, chiasma, and precommissure; (*d*) membranous, consisting only of the endyma and the pia, constituting a tela, *e.g.*, the roofs of the metacele (metatela), of the diacele (diatela), and of the prosocele. The plexuses (metaplexus, etc.) are special modifications of the telas (§ 24). The metapore is here represented as an interruption of the metatela. If, as now seems probable (§ 83), it is an evagination, there still remains the difficulty of determining its extent, and the best mode of representing it.

D. For the sake of comprehensiveness certain features are included which do not occur in all vertebrates—*e.g.*: the metapore (in man and a few others); the pons (mammals only); the medicommissure (mammals and some

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* This, the "isthmus cerebri" of some writers, must not be confounded with the "isthmus rhombencephali" of others, which includes a portion only of the mesencephalon (see Table I.).

* The callosum and fornix are omitted because their inclusion would have caused undesirable complications.

TABLE I.—COMPARATIVE VIEW OF THE SEGMENTAL SCHEMAS ADOPTED BY—

THE ANATOMISCHE GESELLSCHAFT IN 1895.

	Partes ventrales.	*Partes dorsales.*
VI. TELENCEPHALON.	Pars optica hypothalami.	Corpus striatum; rhinencephalon; pallium.
V. DIENCEPHALON.	Pars mamillaris hypothalami.	Thalamus; metathalamus; epithalamus.
IV. MESENCEPHALON.	Pedunculi cerebri.	Corpora quadrigemina.
III. ISTHMUS RHOMBENCEPHALI.	Pedunculi cerebri.	Brachia conjunctiva; velum medullare anterius.
II. METENCEPHALON.	Pons.	Cerebellum.
I. MYELENCEPHALON.	Medulla oblongata.	
	Pars ventralis.	*Pars dorsalis.*

THE ASSOCIATION OF AMERICAN ANATOMISTS IN 1897.

I. RHINENCEPHALON.	Bulbi olfactorii with their tracts, part of the aula and of the precommissure.
II. PROSENCEPHALON.	Palliums, connected by part of the aula and part of the precommissure.
III. DIENCEPHALON.	Thalami, including the chiasma; genicula.
IV. MESENCEPHALON.	Crura and quadrigeminum.
V. EPENCEPHALON.	Cerebellum; pons; preoblongata.
VI. METENCEPHALON.	Postoblongata.

reptiles); the paraphysis (not found in mammals*); the chiasma (absent in teleosts).

E. The dotted areas represent fibrous parts crossing the meson whether directly (precommissure) or obliquely (chiasma); the similar representation of the medicommissure is not warranted by its cellular structure in mammals.

F. Other differentiations of the substance of the parietes are not indicated, *e.g.*, into the alba (white substance) and the cinerea (gray).

G. The hypophysis is notched and crossed by the broken line to indicate its twofold source, neural (*n*) and enteric (*e*) § 146. The ectal line which elsewhere represents the pia enveloping the brain should not be so interpreted for the enteric portion.

H. The indentation of the precommissure merely emphasizes the relations of its two portions to the rhinencephal and the prosencephal respectively (§ 364).

I. The indentation of the mesencephalic roof represents the transverse furrow which—in mammals only—demarcates the quadrigeminum into a pregeminum and a postgeminum; the former, I believe, is always the larger, but the ratio is not known to me. No attempt is made to indicate the intergeminum ("interoptic lobes" of Spitzka).

J. The two indentations of the cerebellum, ental and ectal, represent respectively the fastigium (§ 95) and the furcal sulcus (§ 117), but without implying their exact collocation.

K. The crista has been observed in comparatively few vertebrates and its morphological significance is undetermined (§ 366).

L. *The Absence of Flexures.*—Granted that no brain is perfectly straight and that many are strongly flexed in one or more places, how many flexures shall be represented and what shall be their extent? The only impartial condition of the axis is straight (§ 38).

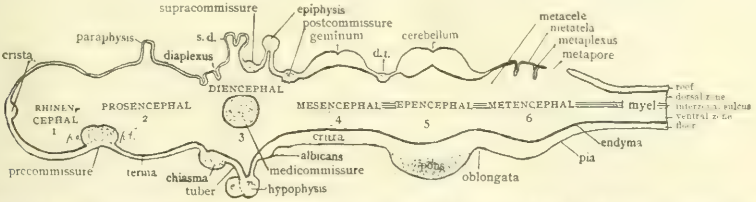

FIG. 675.—Provisional and Imperfect Schema of the Brain as if Medisected; intended to approximate the "least common multiple" of the brains of vertebrates above the lancelet.

Abbreviations: In the floor, at the sides of the precommissure, *p. o.* designates the olfactory division (*pars olfactoria*) and *p. t.* the cerebral or temporal division (*pars temporalis*) of that commissure. In the hypophysis, *e*, designates the portion derived from the enteron (prehypophysis), and *n*. the strictly nervous portion (posthypophysis). In the roof, *s.d.* designates the dorsal sac (*saccus dorsalis*), and *d. t.* the decussation of the trochlear nerves (*decussatio trochlearis*). The numerals indicate the six definitive segments beginning with the most cephalic (compare Fig. 680).

M. On the same principle the dorsal and ventral outgrowths, paraphysis, dorsal sac (*s.d*), epiphysis, and hypophysis, are made to project nearly at right angles with the brain axis. In many vertebrates the hypophysis tends caudad, but in man it tends rather in the opposite direction, and in the goose-fish (*Lophius*) it lies far cephalad of the rest of the brain.

N. *The Dorsal and Ventral Zones.*—It is conceded that the myel is demarcated by an interzonal sulcus ("*sulcus limitans ventriculorum*" of His) into a dorsal zone which is sensory and a ventral which is motor; also that the sulcus and zones are represented more or less distinctly in the caudal half of the brain. On the figure the sulcus is conventionally indicated by the segmental names, *mesencephal*, etc., and by the three lines connecting them. But I have as yet been unable to satisfy myself of the

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[*] See the turtle's brain Fig. 680. The part is briefly discussed by Minot, 1892, 690, and by Studnička, 1895.

continuance of these features in the cephalic half of the brain (see § 153).*

O. Comparisons will be made naturally and justly with (*a*) representations of the primary neural segments or true neuromeres like (*b*) that of Charles Hill (1899, 1900), (*c*) the schema of Prof. Wilhelm His (1893) which was adopted in 1895 by the Anatomische Gesellschaft (His, 1895), (*d*) that of Huxley (1871), (*e*) my own successive attempts, especially that in the first edition of this work, vol. viii., p. 114, which was substantially identical with that in the last four editions of Quain's "Anatomy." From all four it differs in the recognition of the olfactory region of the brain as a definitive segment; from the first it differs also in regarding adult rather than early embryonic conditions—thus in recognizing the final, actual, or definitive segments rather than the primitive or potential neuromeres; from the second, in addition to minor points that may be mentioned later, it differs also in the greater regard for the conditions in the lower vertebrates; in the non-recognition of the "isthmus rhombencephali" as a definitive segment, in the method of enumerating the segments and in the names of some. See also my papers, 1897, *a*, and 1899, *a*.

P. *The Number of Segments.*—On this point the differences of opinion and usage are wide and radical; my own views have changed more than once and may change again. No one admits more fully the need of further information and of more logical interpretation. The practical question that now confronts us—investigators, teachers, and students alike—is this: In the present state of our knowledge, ignoring no known conditions of the brain, adult or developmental, and assigning at least equal weight to the lamprey and to the hag as to man, what number of transverse divisions shall be recognized, so as to facilitate the extension and comprehension of the main features of a highly complex organ while not hindering the elucidation of the mysteries as yet unsolved? These divisions must be natural, not necessarily identical but at least comparable, and neither so few as to be useless nor so many as to be inconvenient. The practical requirements are met by the numbers five and six. Five definitive segments were recognized in Quain and in the first edition of this work. Six are now recognized by both His and myself; but, as will be seen later, the first of mine (rhinencephal) is not admitted by him, while I am unable to see a definitive segment in the "isthmus rhombencephali."†

Q. In regarding the olfactory bulbs, their tracts or crura, [illegible] as constituting a definitive segment, the rhinencephal, I may be unduly influenced by the conditions in certain other vertebrates (Figs. [illegible]) [illegible].

R. [illegible]

S. *The Relative Size of the Segments.*—This point is analogous to that respecting the direction of the axis of the entire brain (L). Even were the preponderance of the cerebrum in man and other mammals to be indicated the precise ratio would not be easy to fix. But in some sharks the cerebellum is very large; in Teleosts the mesencephalic lobes are most conspicuous; in *Chimaera* the diencephal is greatly prolonged (W., 1877, *a*); in the electric ray the postoblongata (metencephal) equals in size the remainder of the brain. Finally, to offset the relative insignificance of the olfactory bulbs in the Primates and their total absence in certain Cetacea, they compare favorably with the other segments in many Reptiles and Amphibia, in the hags (Fig. 790) they are as wide as the cerebrum, and in the lamprey (Fig. 789) they surpass it in bulk. There seems to be no escape from the conclusion exemplified in the schema, viz., that the definitive segments are potentially equal in size.

T. *The Numeral Designations of the Segments.*—In accordance with the rule (to which there is, so far as I know, but a single exception*)—viz., that the members of any cephalo-caudal series of similar parts, *e.g.*, ribs and vertebræ, should be numbered beginning with the one next the head—anatomists have hitherto generally designated the segment next the myel as last and the one at the other extreme as first. That plan is adhered to in Fig. 674, and throughout this article. The contrary enumeration was introduced by Professor His in 1893. It has been adopted by the Anatomische Gesellschaft, and there is likely to result confusion such as would attend the reversal of the universal method of enumerating the cranial nerves.

U. *The Segmental Names.*—As may be seen from the table of His reproduced in the latter part of the article *Brain, Development of*, and from the abstract of it in Table I., the most radical differences concern the two segments next the myel. The Association of American Anatomists follows Quain in designating the most caudal *metencephalon* and the next *epencephalon*. The Anatomische Gesellschaft follows Huxley in applying *metencephalon* to the penultimate segment and designating the ultimate by [illegible].†

§ 46. Fig. 677 illustrates: A. The great relative bulk of the head, constituting about one-half of the entire body.

B. The indications of encephalic segmentation by slight furrows, represented by the converging lines upon the side of the head.

C. The prominence of the mesencephal at this period, forming the "top of the head."

D. The sharpness of the cranial flexure, whereby two of the segments appear in a dorsal view, and two in a ventral, while the fifth appears partly in both views, as shown by Figs. 677 and 678.

E. The conditions of the eye and ear; the greater differentiation of the [illegible] presence of a short but distinct tail.

§ 47. Fig. 678 illustrates: A. The distinctness of the myel and its "central canal" even to the root of the tail.

B. The sudden and great expansion to constitute the [illegible] ("fourth ventricle").

C. The marked constriction between the mesocoele and the [illegible].

D. The existence on the contrary of the greatest

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* [illegible]

† [illegible]

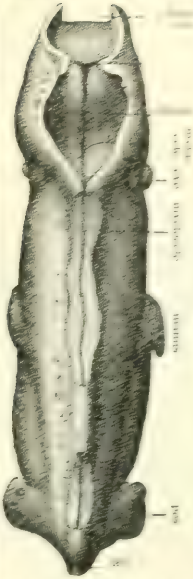
* [illegible] that in the famous work of ALBINUS, [illegible]

† [illegible]

[illegible]

[illegible]

[illegible]



[illegible]

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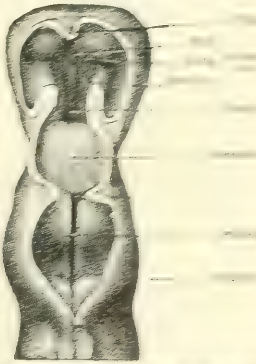


[illegible]

[illegible]

ized vertebrates, *e.g.*, the turtle (Fig. 680) and the hag (Fig. 782), and even in mammals where the cerebrum is less preponderant than in man. But with mammals the other segments are more easily recognized if the cerebrum and cerebellum are either tilted in opposite directions as in the rabbit preparation (Fig. 681), or the former is also medisected as in the cat (Fig. 682), or both partly cut away as in the sheep (Fig. 794).

§ 51. *Fig. 680 illustrates:* A. The availability of this reptilian brain for the exemplification of certain features of the organ; it is large as compared with that of amphibia and most other reptiles; the cerebrum and cerebellum do not overtop the other parts so as to obscure their serial relations; excepting the pons and callosum most of the commissures are represented; and the cranial flexure is slight (Fig. 671).

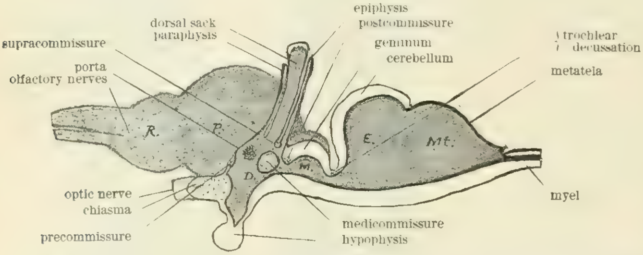


FIG. 680.—Mesal Aspect of the Medisected Brain of the Green Turtle, Chelone midas. × 1. From nature and from the paper of O. D. Humphrey, 1894. The letters R., P., D., M., E., and Mt., designate respectively the six segments, rhinencephal, prosencephal, diencephal, mesencephal, epencephal, and metencephal. The first and second are placed on the pial surfaces of the olfactory bulb and hemicerebrum; the other four are within the cavities.

B. The departure from the schematic brain in two respects: (*a*) the reduction of the mesal portion of the rhinocele and prosocele to a slight cavity, the aula, opening laterad by the porta; (*b*) the crowding of the cephalic segments caudad, occasioning the diencephalic flexure, and bringing the aula and porta dorsad of the diacele instead of cephalad of it.

C. The elongation and close apposition of the three dorsal outgrowths, paraphysis, dorsal sack, and epiphysis.

D. The relatively large size of the olfactory bulb, and the duplicity of the olfactory nerve.

§ 52. *Fig. 681 illustrates:* A. The greater obviousness of the segmental constitution than with the adult human brain from any point of view.

B. The smaller relative size of the cerebrum than in man or the cat (Fig. 682).

C. The much less extent of the callosum than in man or the cat, making it possible to uncover the diencephal without the medisection required in the cat (Fig. 682).

D. The presence of a distinct roof of the diacele, the interthalamic space, notwithstanding the cerebrum has been tilted.

E. The relation of this roof, the diatela, to the habenas, the ridges demarcating the dorsal and ectocelian from the mesal or entocelian surfaces of the thalami.

F. The non-adhesion of the thalamus to the hemicerebrum in any way such as to indicate that the former enters into the composition of the paracelian floor.

G. The more nearly equal size of the lateral (pileums) and mesal (vermis) lobes of the cerebellum, and the concomitant absence of the vallis which is so obvious on the caudal aspect of the adult human cerebellum (Figs. 672 and 697).

§ 53. *Fig. 682 illustrates:* A. The possibility, even with so high a mammal as the cat, of making a preparation that, without disturbing the essential morphological features of the organ, may exhibit portions of all of the encephalic segments excepting the last, the metencephal.

B. The tendency of three of the encephalic segments to overlap those caudad of them. The cerebellum, the epencephalic roof, partly conceals the postoblongata, metencephal, in its natural attitude; in the present figure it is tilted caudad. The mesencephal (gemina or optic lobes) is covered partly by the cerebellum and partly by the cerebrum, and also at the sides overlapped somewhat by the postgeniculums, elements of the diencephal; in the figure these bodies are in deep shadow, crossed by the line 3 on the right, and on the left by the line leading to the postgeminum. Finally, the cerebrum conceals the diencephal and mesencephal, part of the rhinencephal, and even the cephalic slope of the cerebellum in the cat, while in man it alone is visible when the brain is viewed from the dorsal aspect (Fig. 664).

C. The relations of the callosum and fornix to the two hemicerebrums, as lines of secondary adhesion between the two, the one dorsal and the other ventral.

D. That the triangular area, hemiseptum, is really only a portion of the mesal wall of either hemicerebrum, which has been intercepted between the two lines of junction above named.

E. That the interval, pseudocele ("fifth ventricle") between the two hemiseptums, has no connection with the true encephalic cavities.

F. That the callosum and fornix are in no sense parts of the roof of the diacele (third ventricle): this is constituted by (1) its proper endyma, (2) the pia covering this, as all other parts of the brain, (3) the pia pertaining to the fornix, which layer of pia, with the layer (2) and the intervening vessels, constitutes the velum.

G. Incidentally it may be remarked that the cruciate fissure in cats and dogs constitutes, as it were, a gash across the mesal margin near the cephalic end of the hemicerebrum; it appears, therefore, upon both the mesal and the dorso-lateral aspects. The well-known and easily experimented-upon motor areas of the limbs occupy the U-shaped gyre between the cruciate and coronal fissures. It does not follow, however, that the cruciate fissure and the human central fissure are homologous (§ 303).

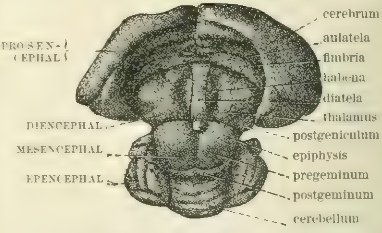


FIG. 681.—Dorsal Aspect of the Brain of a Young Rabbit, the Cerebrum and Cerebellum Pushed in Opposite Directions.

Preparation.—While fresh, the cerebellum was tilted caudad and the hemispheres cephalad, and the velum removed; the brain was then placed in strong alcohol so as to retain the desired shape. The segmental names are at the left, the names of parts at the right. The specimen has been lost or destroyed.

§ 54. *Relative Size of the Segments in the Embryo and the Adult.*—In the embryo at one period the mesencephal is the most prominent region, and it remains the largest in some fishes; in the adult human brain it is one of the least conspicuous.

§ 55. *Segmental Overlapping.*—Although originally subequal in size, certain segments early manifest a tendency to extend beyond their neighbors in one or more directions. In man and the mammals generally this overlapping is in inverse ratio to the original size of the parts. The mesencephal, at one period most prominent, is encroached upon by the diencephal at the sides, by the pons ventrad, the cerebellum dorsad, and all are eventually covered by the cerebrum, primarily a comparatively insignificant portion of the brain.

§ 56. This segmental overlapping is, upon the whole, greater caudad than cephalad, most of the segments presenting something like the "rake" of the mast of a ship. The cerebellum, for example, not only extends both cephalad and caudad from its connections with the epencephalic floor, but is tilted distinctly caudad (Figs. 670, 687, and 693).

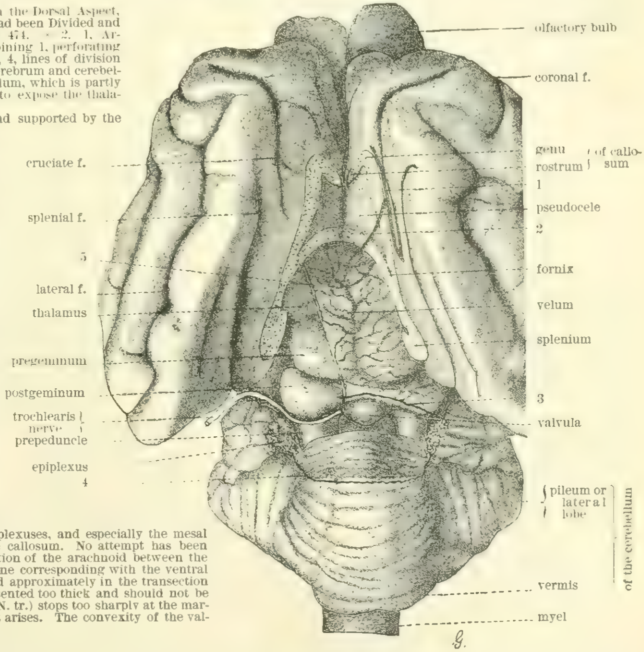
§ 57. Transections at any level caudad of the aula usually affect two or more segments. This is illustrated in the following diagrams (Fig. 683).

§ 58. *The Caudato-thalamic Fusion.*—The relations of the prosencephal to the diencephal are further complicated by the intimate fusion of the sides of the latter (thalami) with the floors of the former (caudatums). Although, therefore, in the early embryonic stages (Fig. 671) it is very easy to distinguish between the two segments, there is some difficulty in the adult. For convenience, in the present article, the capsula ("internal capsule") is adopted provisionally as the boundary, so far as regards the thalamus and the lenticula (part of the striatum). But the same medullary stratum intervenes between the lenticula and the caudatum, both prosencepalic parts, and the whole subject requires further elucidation.

FIG. 682. The Brain of a Cat from the Dorsal Aspect, After the Callosum and Fornix had been Divided and the Hemicerebrums Divaricated; 474. × 2. 1, Artery (precerebral ?); 2, artery joining 1, perforating the callosum from the velum; 3, 4, lines of division of the arachnoid, between the cerebrum and cerebellum; 5, line of division of the velum, which is partly removed on the left side so as to expose the thalamus and gemma of that side.

Preparation.—While fresh and supported by the *basis cranii*, the hemicerebrums were carefully separated so as to expose the callosum; this was divided, beginning with the splenium; then the fornix until the incision reached the point of attachment of the velum. The cerebellum was tilted caudad and the arachnoid between it and the postgeminum divided; the cerebellar edge of the arachnoid is represented by the line 4. The valvula is shown as if inflated with air. On the left side, along a line (5) extending obliquely caudo-mesad from under the margin of the fornix, the two layers of pia constituting the velum were divided, and the part at the left removed so as to expose more distinctly the postgeminum, pregeminum, and thalamus. The cerebral pia was removed. A similar preparation of the human brain is very desirable, but difficult to make, on account of the weight of the cerebrum.

Defects. The arteries should have been injected with a red mass, for the better exposition of the pia, the plexuses, and especially the mesal artery (2) which penetrates the callosum. No attempt has been made to show the lines of reflection of the arachnoid between the two hemicerebrums, along a line corresponding with the ventral margin of the falx and indicated approximately in the transection (Fig. 732). The fornix is represented too thick and should not be dotted. The trochlearis nerve (N. tr.) stops too sharply at the margin of the valvula, from which it arises. The convexity of the valvula is too sharply defined.



§ 59. *The Segments Primitively Mesal and Single.*—This view is generally accepted with regard to the diencephal and the parts caudad of it on account of the familiar conditions of early development. The prosencephal likewise, although commonly described as a pair of lateral masses, is single in "fishes" (see the figures and statements in connection with that segment, §§ 158–162). The case of the rhinencephal is less readily disposed of, and will be stated in connection with that segment (§ 370).

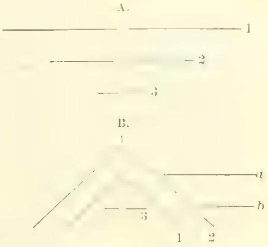


FIG. 683.—Diagrams Illustrating the Lateral Overlapping of the Mesencephal by the Two Segments Cephalad of It. The transverse axes of the prosencephal, diencephal, and mesencephal are indicated by the lines 1, 2, 3, respectively; in A they are directed laterad, as in the early embryonic stages; at B they are inclined caudad, and transections at *a* or *b* would cut two or three segments instead of one.

§ 60. *Potential Triplicity of the Encephalic Segments.*—Although primarily mesal and simple, each segment presents at some period and in some vertebrates a distinctly threefold condition, with one mesal and two lateral portions. The prosencephalic triplicity is exhibited in all air-breathing vertebrates and some aquatic forms (Dipnoans, etc.); with birds and frogs the mesencephal is markedly tripartite (Fig. 682); with man and other mammals, and likewise with some other vertebrates, the epicele presents more or less extensive "lateral recesses" (Figs. 669, 684, 698). The embryonic diencephal protrudes at either side an optic vesicle that becomes the retina and optic nerve.

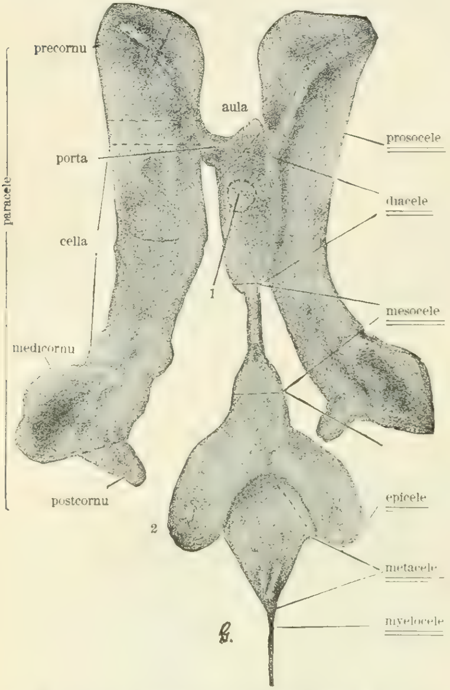


FIG. 684.—Cast of the Encephalic Cavities, Ventral Aspect; approximately correct. × 1/2. (From Weisker, modified.) The names at the right, doubly underlined, designate five divisions of the encephalocele, together with the slender myelocele (central canal of the spinal cord). The metacele and epicele together constitute the "fourth ventricle" of the text-books; the mesocele corresponds to the aqueduct or iter; the diacele equals the "third ventricle" less the aula, which is the mesal part of the prosocele; prosocele includes all not already specified, viz., the mesal aula, the lateral paraceles ("lateral ventricles"), and the two portas through which they are continuous. The names at the left designate the parts of the paracele, viz., the cella, extending caudad from the porta; the precornu, extending cephalad; the medicornu, extending in a spiral direction laterad, ventrad, cephalad, and mesad, successively; and the postcornu projecting caudad from the cella. 2 is placed near the tip of the right lateral recess of the epicele. The larger part of the figure is modified from a photograph of the wax model made by Weisker, of Freiburg. The metacele, myelocele, and part of the epicele are from a cast of the cavities in a child. The ventral aspect was chosen in order to display to better advantage the uninterrupted series of mesal cavities, and the portas.

Defects.—I doubt whether any part represents the corresponding cavity accurately. The portas are too long (compare Fig. 718). The diacele presents neither the orifice for the medicommissure (the presumed location of which is indicated by the dotted circle (1) just caudad of the portas) nor the marked ventral extension toward the hypophysis. The medicornua are not sufficiently curved; in reality the extremity of each approaches the diacele within about 2.5 cm.; the postcornua are too short; the boundaries of the epicele are vaguely and perhaps incorrectly indicated, and the lateral recesses (2) should be longer.

§ 61. *Fig. 684 illustrates:* A. The continuity, general form, and relative size of the several divisions of the adult human encephalocele, as viewed obliquely from the ventro-dextral aspect.

B. The obvious triplicity of the prosocele, and the existence of lateral extensions of the epicele.

C. The slenderness of the mesocele as compared with its relative size in the embryo (Fig. 680) and in the adults of some other vertebrates (Fig. 685).

D. The general modifications of the primitive and typical condition of the encephalic cavity which led the older anatomists, and still lead some of their modern successors, to regard the whole as comprising four "ventricles," a first and second (lateral), a "third," and a "fourth," the aula being ignored and the mesocele considered merely as a "passage from the third ventricle to the fourth."

§ 62. *Fig. 686 illustrates:* A. An arrangement and circumscription of the encephalic cavities in the adult cat (an accessible mammal), essentially identical with that in the human adult (Fig. 735) and fetus (Fig. 716), and in vertebrates generally.

B. The great differences in size and shape between the various divisions of the encephalocele; the mesocele is little larger than the myelocele, and is tubular; the diacele is narrow but high; the metacele wide but shallow; the epicele is very irregular; the myelocele is patent throughout, while in man it is nearly obliterated. The epicelian lateral recesses are not exposed, so the triple constitution of a typical segmental cavity is exhibited only by the prosocele, with its mesal, aula, and lateral paraceles.

C. The different constitution of the celian parietes. The roofs of the aula, portas, and metacele are membranous telas, with plexuses on the ental surface.

D. The reduced thickness of the parietes near the rima, constituting the fimbria, one of the riparian or marginal parts.

E. The apparent interruption of the wall of the medicornu at the rima ("great transverse fissure"). On close examination, however, although the proper nervous parietes are absent, the intruded pial fold (paraplexus) is seen to be covered by the endyma reflected from the adjoining parts, so that the injected alcohol was completely confined.

F. The not very obvious relation of the ectal furrow, hippocampal fissure, to the ental elevation or colliculus, hippocamp; on the right the line from *postgeniculum* crosses the end of the fissure, which is not otherwise indicated.

G. The relations of the alba (medulla) to the ectocinerea (cortex) and the entocinerea ("central tubular gray"); the metepencephalic entocinerea has been removed in exposing the cavities, but it is distinct and abundant at the sides of the mesocele (aqueduct), of the diacele, consti-

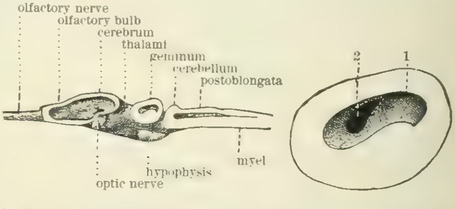


FIG. 685.—Left-hand figure: Brain of Frog Seen from the Left After Removal of Parts of the Left Side; 654. × 1.5. Right-hand figure: Enlargement of the Geminum (Mesencephal), so as to show more distinctly the lateral cavity of the mesocele and the orifice (comparable with the porta) by which it communicates with the mesal cavity.

tuting the thalamus, and of the prosencephalic precornu, constituting the caudatum and—unexpectedly—the hemiseptum and column of the fornix, all which were distinctly gray in the fresh preparation.

H. The caudal extension of the cerebrum so as to reach the cerebellum, and thus conceal the lateral aspect of the intervening segments, diencephal and mesencephal.

I. The fusion of the thalamus with the caudatum, of the diacelian side wall with the paracelian floor. The line of junction of the two segments may be regarded as indicated approximately by the word *dien.*

J. The absence or inconspicuousness of the lenticula, claustrum, and insula (compare Fig. 782).

K. The less width of the diencephal than in man, so that the geniculums maintain their proper morphological relation of cephalic (pre) and caudal (post), rather than of lateral, or "external," and mesal, or "internal," as in man.

L. The extension of the paraceles, the proper cavities of the hemicerebrums, caudad from the aula even farther than cephalad, thereby warranting the diagrammatic representation of the paraceles as lateral extensions, not cephalic only.

M. The absence of a postcornu in the cat as in most other mammals, the exceptions being man, monkeys, seals, porpoises, and some dogs.

N. The distinctness of the crista in the cat. It is not named on the figure, but may be seen as a conical elevation at the cephalic side of the aula; the line from *aula* points at it.

§ 63. *Celian Circumscription.*—The facts of development and comparative anatomy, and analogy with other hollow organs warrant the presumption that the encephalic cavities communicate only with one another and with the myelocele. Any communication with the ectal surface is presumably artificial, excepting, perhaps, at the metapore ("foramen of Magendie") and the lateral recesses (§§ 78, 98).

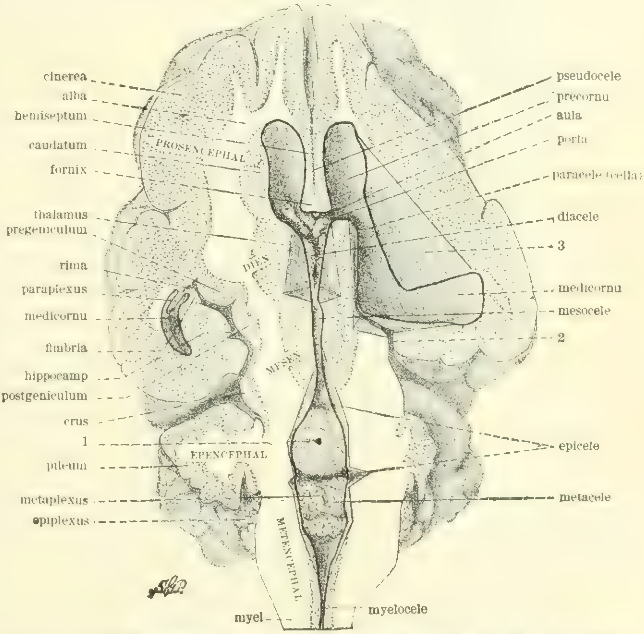


FIG. 686.—The Encephalic Cavities of a Cat, Exposed from the Ventral Side; 479. × 2. 1, The valvula, which is so thin in the cat that the cerebellar folia show dimly through it (the line is interrupted just above the L of EPENCEPHAL); 2, the narrow space between the lateral aspect of the mesencephal and the overlapping hemicerebrum; in anthropotomy this is commonly reckoned as part of the "great transverse fissure"; 3, obliquely cut surface, left by the removal of the caudatum and adjacent parts of the left hemicerebrum.

Preparation.—The brain was exposed from the ventral side and left in the calva for better support. the cavities were alinjected so as to harden the parietes and keep them apart. Successive slices were removed until the portas and aqueduct (mesocele) and myelocele were exposed. With a narrow-bladed knife the walls of the diacele (including the medicommissure), epicele, and metacele were cut away obliquely; also on one side (the right of the preparation, but the figure is reversed so that it appears on the left) the caudatum, hippocamp, and part of the thalamus, so as to expose the continuity of the precornu and medicornu. The olfactory bulbs were removed with the ventral portion of the cerebrum. The boundaries of the cinerea (cortex, etc.) and alba (medulla) were ascertained by comparing the similarly exposed surface of a fresh brain; some of the differences between the two sides are due to a slight difference of the section-levels.

Defects.—The brain should have been prepared in a chromic-acid solution, or injected with the red mixture, so as to differentiate the alba and cinerea.

§ 64. *Endymal Continuity.*—The endyma is the essential and absolutely constant constituent of the celian parietes; hence in all figures purporting to illustrate celian circumscription the line representing the endyma should be distinct and uninterrupted, excepting where discontinuity has been demonstrated.

§ 65 *Fig. 687 illustrates:* A. The sharpness of the cranial or mesencephalic flexure in man. Compare the sheep (Fig. 794) and the turtle (Fig. 680).

B The continuity of the endyma lining the mesal series of cavities excepting at the metapore, and the concomitant completeness of the celian circumscription.

C. The non-communication of the pseudocele with the true cavities. (The meninges and blood-vessels are considered under Fig. 801.)

§ 66. In tracing the continuity of the endyma at the meson it is best to begin with a region where a rupture could hardly occur in either floor, roof, or sides, and where also a transection is most readily effected when the entire brain is to be studied in two parts, a cerebral and a cerebellar portion. This "place of election" is the mesocele ("aqueduct" or "*iter a tertio ad quartum ventriculum*").

A. The endyma covering the floor of the mesocele may be traced caudad (actually almost directly ventrad) with slight depressions and elevations through the oblongata to the myel where it lines the slender myelocele, the "canal of the cord."

B. Recommencing at the same point in the mesocele, the floor endyma turns quite sharply ventrad over the cephalic curvature of the crus, passes the albicans, and reaches a region where the floor is thin and frequently torn in removing the brain. This is the tuber, commonly called "*tuber cinereum*," which is continuous with the infundibulum, and thus with the hypophysis. The cephalic part of the tuber is reinforced by the chiasma, the ental margin of which presents a marked transverse ridge, sloping caudad into the tuber and cephalad into the optic recess. In Figs. 689 and 708, the chiasma and tuber are shown with the hypophysis attached; but in Fig. 672 it is detached, leaving an orifice, the lura.

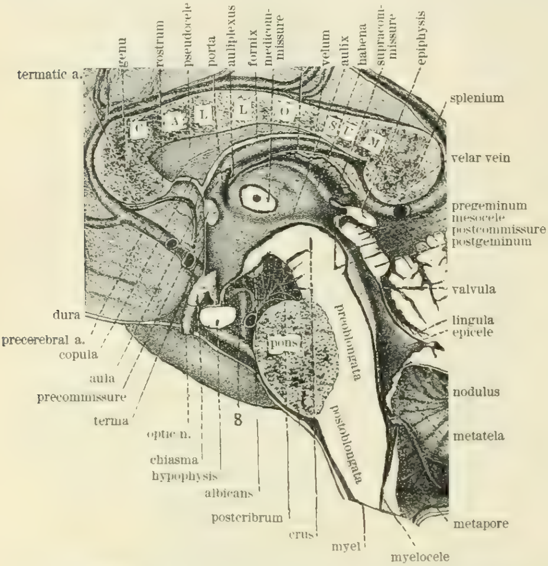


FIG. 687.—The Mesal Cavities of an Adult Brain Exposed from the Left, with Their Immediate Parietes. × .65. Fig. 801 represents the entire meson of the same specimen on a smaller scale, and its mode of preparation is there described.

Defects.—In addition to those specified under Fig. 801, the most serious are: (*a*) the non-representation of the postpontile recess, the mesal depression just caudad of the pons, shown in Fig. 702, 2; (*b*) the presence of the line curving dorso-caudad from the rostrum of the callosum; (*c*) the imperfect indication of the membranous parietes of the dorsal sac, the pouch lying upon the epiphysis; (*d*) the non-designation of the diacele.

C. Directly dorsad from the chiasma, the cephalic wall of the diacele is the terma (*lamina terminalis*, or *l. cinerea*), so thin and delicate as not infrequently to be ruptured during the removal or manipulation of the brain. The proper nervous material of the terma seems hardly more substantial than the lining endyma and the covering pia, here represented by the ental and ectal lines. The ectal aspect of the terma is shown in Fig. 711.

D. Suddenly there is a marked thickening of the cephalic wall, from the reinforcement, so to speak, of the terma by a fibrous cord, oval or elliptical in section. This, the precommissure, connects the olfactory bulbs and portions of the cerebrum upon opposite sides, and hence belongs to both the rhinencephal and prosencephal; the cavity just caudad and dorsad of it is the aula, the mesal portion of the rhinocele and prosocele; §§ 362–364.

E. From the precommissure caudad to the roof of the mesocele the course of the endyma is extremely irregular, and the nature and shape of the roofs are very diverse. The immediate roof is largely membranous, and the condition is further complicated by blood-vessels large and small, and by plexuses. Finally, the parts lying directly upon the meson differ materially from those just laterad of it, and as the chances are altogether against a medisection being exactly mesal in the whole of its course, there is nearly a certainty that upon the first inspection one will miss anticipated features and see what one does not understand.

F. The recognition and comprehension of the actual facts in a given preparation will be facilitated by consulting the diagram (Fig. 725), and the representations of the brains of the cat and rabbit (Figs. 681 and 682). The important point to bear in mind is that the complete circumscription of the mesal encephalic cavities would be unaffected were the entire cerebrum removed, including the callosum, hemiseptum (the lateral wall of the pseudocele), and fornicommissure (the mesal continuity of the fornix), down to the point where the heavy line representing the endyma leaves the narrow, white area representing the fornicommissure to cross the convex surface of the fornicolumn and be reflected upon the auliplexus. The details of this, the aulic and portal region, are more clearly seen in the enlarged figures of the porta (Figs. 721 and 719).

G. From the auliplexus (at or very near the meson) or from the portiplexus (if the section plane passes through the right or left porta instead of the mesal aula) the endyma may be traced caudad upon the ventral surface of a membranous fold, the velum. Strictly speaking, between the endyma and the velum, which is a fold of pia, intervenes the remnant of the primitive nervous roof of the diacele. This may persist in some animals, but in the adult cat and in man, so far as I am aware, there is practically nothing between the pia constituting the velum and the endyma. At each side of the meson there depends a more or less distinct vascular fringe, the diaplexus, continuous with the auliplexus, the portiplexus, and thus with the paraplexus, these last three being successive members of the prosoplexus.

H. The relations of the endyma to the velum and plexuses are more clearly shown in Fig. 732, representing a transection of the diacele. There also are shown the relations of the habena. This is a low ridge following a curved line along the mesal aspect of the thalamus from the dorsal end of the porta to near the epiphysis; it is covered by endyma, but just dorsad of it, dimly seen in the figure, is a shallow furrow, the habenal sulcus, from which the endyma is reflected first dorsad, and then mesad, upon the velum and the diaplexuses. The habena unites with its opposite (fellow of the other side) at the supracommissure. The endyma line is seen to leave the velum, and descend to the dorsal (really cephalic) surface of the epiphysis, whence it extends cephalad to and over the margin of the supracommissure, then into and out of the epiphyseal recess, and over the convex cephalic surface of the postcommissure; thence it enters the mesocele, where the tracing of its continuity was begun, only it is now the lining of the roof, the geminal bodies, instead of the floor.

I. Continuing caudad, there is but slight change in the direction of the roof of the mesocele; a great reduction in its thickness occurs in the transition from the postgeminum to the valvula. The succeeding part, the lingula, is somewhat thicker and trends slightly dorsad, to become continuous with the cerebellum proper. The cavity here resembles a gable roof, with a sharp dorsal angle. The caudal slope is formed by the nodulus, a comparatively massive mesal lobe; but from its margin, commonly more rounded than appears in this figure, the endyma

TABLE II.—PROVISIONAL GROUPING OF SOME NEURAL PARTS ACCORDING TO THEIR SEGMENTS AND SOME OTHER CHARACTERS.

	1. Segment.	2. Chief constituent.	3. Cavity.	4. Membranous portion.	5. Plexuses.	6. Thin and riparian parts.	7. Commissures, etc.	8. Some other parts.
I.	Rhinencephalon.	Bulbi olfactorii.	Rhinocœlia....	Rhinotela (in some "fishes")	....	....	Præcommissura (pars olfactoria).	Præcribrum, limen, crista.
II.	Prosencephalon.	Cerebrum....	Prosocœlia (including the mesal aula and lateral paracœliæ).	Prosotela (including the mesal aulatela and lateral paratelæ).	Prosoplexus (including the mesal auliplexus and lateral paraplexus).	Tænia, fimbria, pala, terma.	Præcommissura (pars temporalis), callosum, fornix.	Pallium, insula, lenticula, caudatum, paraphysis.
III.	Diencephalon.	Thalami.....	Diacœlia	Diatela.........	Diaplexus	Habena	Supracommissura, medicommissura, chiasma.	Postcribum, tuber, hypophysis, epiphysis, genicula.
IV.	Mesencephalon.	Quadrigeminum.	Mesocœlia.....	Mesotela (in the lamprey).	....	Valvula........	Postcommissura, decussationes tegmentorum.	Crus, tegmentum, crusta, lemniscus, intercalatum.
V.	Epencephalon.	Cerebellum..	Epicœlia......	....	Epiplexus	Lingula........	Pons	Præoblongata, vermis, flocculus, dentatum.
VI.	Metencephalon.	Postoblongata.	Metacœlia.....	Metatela.......	Metaplexus....	Metaporus, ligula, obex.	Decussatio pyramidum.	Pyramis, oliva, trapezium.
VII.	Myelon......	Myelon......	Myelocœlia....	Myelotela (in lumbar enlargement of birds).	....	....	Commissura ventralis, c. dorsalis.	Conus, filum.

is abruptly reflected, together with the pia which had covered its caudal surface; these two membranes, closely united, and with apparently little or no trace of the primitive nervous roof, constitute the metatela. This is interrupted or modified at the orifice here called metapore, but commonly known as "foramen of Magendie"; in the present figure it is at the point where an artery appears. Later observations indicate that the above accounts of the metatela and metapore do not apply to all specimens; see §§ 77-83.

§ 67. *Encephalic Variations.*—Excepting as to the fissures and gyres, and the pyramidal decussation, treatises upon anatomy seldom refer to variations or anomalies of the surfaces or ental structures of the brain,* yet they are frequent, and sometimes significant, morphologically if not physiologically. So far as I can determine from my own materials, and from figures and descriptions, there is hardly a feature of the human brain respecting which it can be stated confidently what is normal, or how frequently certain peculiarities occur.

§ 68. *Classification of the Parts of the Brain.*—The foregoing account of the brain as a whole constitutes an introduction to the description of each of the six segments, beginning with that immediately succeeding the myel.

§ 69. *Commentaries upon Table II.*—A. It is substantially identical with Table VII. in my paper, 1896, *h.* Compare the tables in the first edition of this work (1889, *a*),

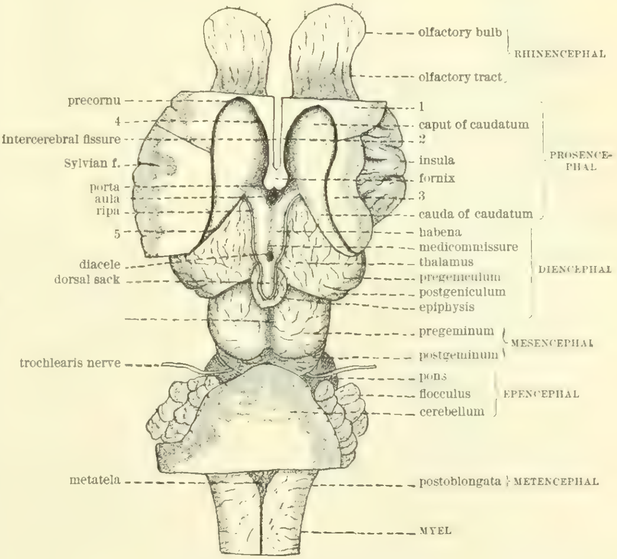


FIG. 688.—Brain of the Sheep, dissected so as to exemplify the segmental constitution of the organ in mammals. From "Physiology Practicums." 1, Cephalic slope of the cut surface of the cerebrum; 2, mesal wall of the paracele at a higher level this would be one of the hemiseptums; 3, horizontal cut surface of cerebrum; 4, the mesal, vertical portion of the paracele; 5, indicates the location of the ripa between the thalamus and caudatum, but it is overhung by the latter so as not to appear in this view; 6, mesal furrow of the pregeminum.

From the cerebellum have been cut both caudal and dorsal parts. On the cut dorsal surface are seen the central alba and the peripheral cinerea, but the outline of the latter is diagrammatic only. At the sides are the tiers of foliums constituting the flocculus.

From the cephalic end of the cerebrum have been cut the parts projecting over the olfactory tracts, but part of the cephalic slope is here marked 1. With the dorsal portion were removed the entire callosum and the fornix excepting the cephalic vertical part. This and the mesal walls of the paracele are really cut at a lower level than the larger cut surface on the left. On the right the insula has been exposed by pushing up and breaking off the overhanging parts. The ectal surfaces, covered by pia, are indicated by irregular lines representing the blood-vessels.

The ental surfaces, covered by endyma, are those of the caudatums in the paraceles, the habenas, medicommissure, and dorsal pouch; and the floor of the aula and portas.

The irregular line laterad of the habena and extending around the endymal area on the epiphysis represents a ripa (shore line). It consists of the cut or torn edges of the pia from the dorsum of the thalamus and of the endyma from the habena which united to form a membranous roof of the diacele, the diatela, which has been removed.

Similarly the pial, dorsal surface of the thalamus is demarcated from the endymal surface of the caudatum by a ripa which meets the other at the porta.

The epiphysis, although a constituent of the diencephal, is tilted caudad so as to rest upon the pregeminum, and the mesal part is covered by the dorsal sack.

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* The subject is treated with unusual fulness by Krause, 1889, 192-195.

and in Wilder and Gage, 1882, 409. From the tables of Schwalbe (1881, 397) and His (1893 and 1895) it differs especially in the absence of any attempt to indicate the relative "values" of the several segments upon embryologic or other grounds.

B. Its purpose is twofold: (*a*) To indicate, according to my present information and belief, the number and constitution of the definitive encephalic segments. (*b*) To illustrate the verbal correlations between the names of the segments themselves (column 1), and those of (3) their major cavities, (4) their membranous parietes, and (5) their vascular plexuses.

C. The Latin form of the names is employed (see § 10).

III. METENCEPHAL.—§ 70. Synonyms: Metencephalon, after-brain, myelencephalon, macromyelon.

§ 71. *Tabular Arrangement of Parts.*—Chief part: postoblongata (caudal portion of "medulla oblongata"). Cavity: metacele (caudal portion of "fourth ventricle"). Floor: postoblongata. Sides: restes ("restiform bodies") and ligula. Roof: metatela and obex. Plexuses: metaplexuses. Orifice or evagination: metapore ("foramen of Magendie"). Decussation: Dec. of the pyramids. Other ectocelian parts and features: Ventral sulcus; ventral column; pyramid; oliva; arciform fibres; lateral column; funiculus of Rolando; tubercle of Rolando; cuneate funiculus; *funiculus gracilis;* clava; ligula; obex. Other entocelian parts and features: Mesal sulcus; *ala cinerea;* postfovea; *eminentia cinerea.*

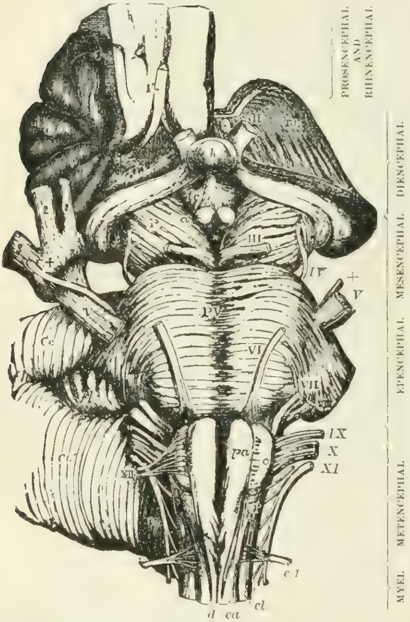

FIG. 689. Ventral Aspect of the Entire Brain Stem. × 1. (From Quain.) Compare Fig. 672. The Roman numerals I.–XII. designate the twelve pairs of cranial nerves; *ii*, the optic tract, more completely exposed than in Figs. 672 and 728; *a*, albicans; *c*, insula; *ca*, ventral column; *c* 1, first cervical, or suboccipital nerve; *ce*, cerebellum; *cl*, lateral column; *d*, ventral fissure of the myel, just cephalad of which is seen the decussation of the pyramids; *e*, pregeniculum; *f*, lemniscus; *fl*, flocculus; *h*, hypophysis; *i*, postgeniculum; *o*, oliva; P, crus; *pa*, pyramid; PV, pons; *r*, "lateral tract of oblongata," direct cerebellar tract; *Sy*, at the ventral margin of the insula, indicates where the basisylvian fissure begins; *tc*, tuber ("*tuber cinereum*"), between which and the hypophysis is the infundibulum; *Th*, thalamus, cut surface; ×, postcribrum ("posterior perforated space"); × ×, precribrum ("anterior perforated space"); +, motor root of trifacial nerve.

Preparation.—The entire left hemicerebrum has been removed by an incision described as passing (in the capsula?) between it and the thalamus; on the right side are left the insula, the adjacent part of the frontal lobe, the olfactory tract, and the precribrum.

Defects.—Several parts, notably the albicantia (*a*) and the flocculus (*fl*), are represented in a somewhat conventional way, and the cimbia ("*tractus peduncularis transversus*") is omitted. The crura, especially the left, are shaded so as to appear twisted.

§ 72. The postoblongata (Figs. 670, 688, 689, etc.) is so obviously a continuation of the myel that if there were no parts cephalad of it, and if it were wholly contained within the spinal canal, it would probably be regarded as merely a somewhat modified region of the myel, comparable with the lumbar enlargement near its other extremity, which also in birds contains a distinct and thin-roofed dilatation, the rhombocele.* There is, therefore, ample etymological warrant for the name *macromyelon* (large myel region), applied by Owen, and for *myelencephalon* (myel-like brain region), employed by Huxley, His, and others. On account, however, of its equally obvious continuity with the preoblongata (especially in animals lacking the pons, *e.g.*, the turtle, Fig. 680); its location, mostly within the cranium; and the number, peculiarity, and vital importance of the nerves connected with it, the postoblongata is conveniently regarded as a definitive segment† of the brain under the title, *metencephal.*

§ 73. Nevertheless both the macroscopic and the microscopic structure of the postoblongata are much better understood in connection with those of the myel. For more details the reader is referred to the articles *Spinal Cord* and *Brain, Histology of the.*

§ 74. *Fig. 689 illustrates:* A. The ectal origins of the cranial nerves.

B. The ventral aspect of the adult insula (comp. Figs. 672 and 781).

C. The continuity of the optic tract with both geniculums.

D. The decussation of the pyramids (see under Fig. 672).

E. The representation of all six segments upon the ventral aspect of such a preparation, including the parts of what is commonly called the "brain stem."

§ 75. The postoblongata differs from a corresponding length of the myel in size, shape, amount of alba, amount and arrangement of cinerea, the extent and form of the cavity, and the nature of its roof.

§ 76. In the myel the two halves dorsad of the commissures are in contact; this is the case also with the caudal extremity of the postoblongata; but for most of its length the originally mesal surfaces are separated by a rapidly widening interval, so that what was mesal becomes successively dorsal, and finally lateral, while what was lateral becomes approximately ventral. These changes materially increase the width of the segment.

§ 77. *Metacele.*—The cavity, a tube in the myel and caudal part of the postoblongata, is expanded into an irregular triangular fossa, the metacele or caudal part of the "fourth ventricle." The roof of this cavity consists of only the lining endyma and the covering pia, constituting the metatela.

§ 78. *Metapore* (*foramen of Magendie*).—In 1826–27 Magendie described (1827, 1–29) an orifice in the roof of the "fourth ventricle" by which that cavity communicates with the subarachnoid space. Magendie designated the orifice as *entrée des cavités du cerveau* or *entrée des ventricules cérébraux.* In 1855 Luschka published a description and figure of the orifice, which he renamed *foramen Magendii.* In the present article these and various other polyonyms are replaced by the mononym *metapore,* Latin *metaporus,* signifying an orifice in the metatela, the membranous roof of the metacele, the cavity of the metencephal.

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* This dilatation of the myelocele has also been called *sinus rhomboidalis*; and this name has likewise unfortunately been applied to the "fourth ventricle," the continuous cavity of the metencephal and epencephal; furthermore, there have come into use derivatives like "rhomboidal lip" and "secondary rhomboidal lip."

† As stated in § 43, this region represents several potential segments or neuromeres.

§ 79. Most later anatomical writers have admitted the existence of the metapore, but the descriptions are commonly brief and the figures unsatisfactory. That by Key and Retzius is suspiciously symmetrical, although it is copied by Schwalbe; Henle's (Fig. 691) is more natural. The best figures and the fullest description are those of Carl Hess, 1885, but few figures have the appearance of having been based upon photographs.

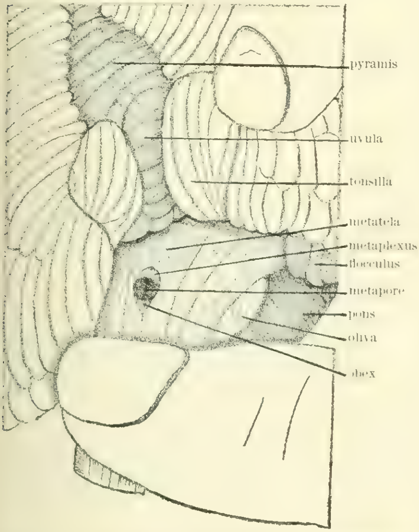


FIG. 690. The Metapore (Foramen of Magendie) as Exposed by the Divarication of the Cerebellum and Oblongata; 318. 1.

Preparation. The brain of an adult Swedish carpenter was removed with great care, by dividing the calva sagittally at the left of the meson, so as to avoid tearing membranous adhesions. The brain was supported on a bed of cotton; the arteries and the arachnoid extending from the cerebellum to the oblongata were cut away and the two parts held asunder with fingers so as to expose the region of the metapore. A photograph was then taken, upon which the drawing is based. After hardening, however, most of the cerebellum was cut away and another photograph taken of the reduced mass. The specimen and both photographs were shown at the meeting of the Association of American Anatomists, December 28th, 1892.

Defects.—The right side of the cerebellum was displaced more than the left, giving rise to the marked obliquity. The metapore itself should be shown on a larger scale. The postcerebellar arteries are omitted; they do not appear distinctly in the first photograph, and no record was made of their locations. This is unfortunate, since in all the cases in which they are preserved their relations to the metapore are close. Had more of the caudal aspect of the cerebellum been included, there might have been shown the line of attachment of the arachnoid at the boundaries of the postcisterna. The wavy lines on the dorsum of the oblongata hardly do justice to the vascularity of the pia covering that region.

§ 80. My own earlier scepticism was based partly upon the absence of any such orifice in the cat and sheep, and upon the presumption in favor of endymal continuity and celian circumscription. The steps of my conversion to the more common view are stated in the first edition of the REFERENCE HANDBOOK and in the papers there referred to. The examination of specimens carefully prepared for the purpose showed that:

(1) The metapore is a normal and nearly constant feature of the human brain at and after birth.

(2) It exists also in apes and some monkeys.

(3) There are two human types, viz.: (*a*) definite, as shown in Fig. 690; (*b*) indefinite, Fig. 691. The latter is the more common.

§ 81. *Fig. 690 illustrates:* A. The existence of a natural orifice in the membranous roof of the "fourth ventricle."

B. The simplicity of the form and relations of the metapore in this specimen. It is mesal, symmetrical, and oval.

C. The appearance of the metaplexuses just within the cephalic margin of the metapore with no such extension upon the cerebellum as is shown in Fig. 691.

§ 82. *Fig. 691 illustrates:* A. The admission of the normal existence of the metapore in the adult by so expert an anatomist as Henle.

B. The attachment of an extension of the metatela from the cephalic border of the metapore upon the uvula and pyramis of the cerebellum.

C. The extension of the metaplexuses upon the thus everted ental aspect of the metatela, whereas in the specimen represented in Fig. 690 they barely appeared at the margin.

D. The topographical relation of the contorted postcerebellar arteries to the metapore.

E. The relation of the flocculus to the lateral recess (Fig. 698).

§ 83. *The Metapore the Outlet of an Evagination.*—In accordance with the general morphological relations of the germ layers Minot published (1892, 676) this passage:

"Several writers have thought that the membrane [endyma] was broken through at certain points, but it probably is really continuous throughout life. The fourth ventricle is to be regarded, then, as an expansion of the central canal permanently bounded by the original medullary walls."

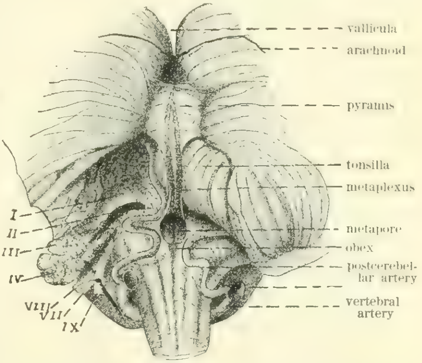


FIG. 691.—The Metapore (Foramen of Magendie) and Adjacent Parts Nearly as Represented by Henle ("Anatomie," iii., Fig. 232).

Preparation.—In the absence of statement by the author, it may be said that the brain was probably removed in the usual way, and the cerebellum tilted cephalad so as to expose its caudal aspect and the dorsum of the oblongata. The left tonsilla was then cut out, exposing on that side the parts marked I, IX, and a continuation of the postcerebellar artery.

I, metatela (*velum medullare posterius*), its lateral portion; II, lateral recess of the metepicele (fourth ventricle) opened by the removal of part of the metatela; III, flocculus; IV, epiplexus (*plexus choroideus lateralis*).

Changes.—The boundary line of the tonsilla has been made more distinct than in the original. In the upper part has been introduced a line to represent approximately the line of attachment of the arachnoid, constituting the dorsal boundary of the postcisterna (see Fig. 806).

Defects.—The margins of the metapore are too sharply defined; this is, perhaps, unavoidable when the parts are upon so small a scale; it cannot be said to bear either way upon the question of the naturalness of the orifice, for the effect of tearing a tough membrane like the metatela would be to leave ragged edges. The relations of the plexuses and accompanying strip of metatela are inadequately indicated, and the writer regrets his present inability to elucidate them. The postcerebellar arteries are represented as if distributed only between the oblongata and cerebellum, and between the lobes of the latter (compare Fig. 806).

In the following year, in a letter which he authorized me to publish in my paper (1893, *d*), Minot made the important suggestion that the metapore represented the mouth (proximal orifice) of an evagination of the endyma. Mrs. Gage found (1893) an evagination in *Amia*, and in *Diemyctylus* a distal orifice. Recently J. A. Blake has gone over the whole subject and shown (1898, 1900) by an admirable series of sections that in cats and dogs and other mammals there is a caudal protrusion of the metatela in the form of a closed sac, but that in man and apes, and (with modifications) in other primates, the larger part of the sac disappears so as to leave a free communication between the "fourth ventricle" and the postcisterna, a subarachnoid space. Blake's paper is accessible to American anatomists, and the bibliography is very complete; much, however, remains to be done.

§ 84. The increased cinerea of the postoblongata consists of (1) the continuous expanded masses of the ventral and dorsal cornua, especially the latter, which, with the modified ventral commissures, constitute the metacelian floor; (2) special masses of cinerea, more or less completely separate, the *nidi* of Spitzka, the niduli of Herrick, the "nuclei" of most writers, constituting the ental or deep origin of certain cranial nerves, and presumably representing detachments of the cornua; (3) the *dentatum olivæ*, or olivary nucleus, a capsule of cinerea within the oliva, resembling the cerebellar dentatum.

§ 85. *Fig. 692 illustrates:* A. The insensible transition from the myel to the postoblongata, and thus from the myel as a whole to the brain as a whole.

B. The apparently sharp demarcation between the epencephal, represented here mainly by the pons, and the adjoining segment. In reality, however, not only do the cephalic and caudal margins overhang the adjoining surfaces to a certain extent (see Fig. 702, 1 and 2), but it is by no means certain that the pons covers no more and no less than the epencephalic portion of the oblongata. In the sheep and cat, for example, the trapezium, here invisible, is exposed (Fig. 794), while with many lower vertebrates the pons is rudimentary or absent altogether, and the boundaries between metencephal and epencephal must be otherwise determined; *e.g.*, the turtle, Fig. 680.

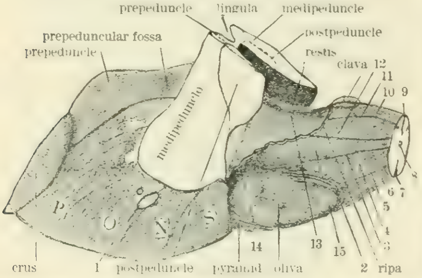


FIG. 692.—Left Side of the Metepencephal After the Removal of the Cerebellum; 2.136. × 1.5. 1, Emergence area of the trifacial nerve, the larger the sensory root, the smaller the motor; 2, the *fibræ arciformes* partly encircling the oliva; 3, line of emergence of the accessorius and of the dorsal roots of the spinal nerves; 4, continuation of the lateral column of the myel; 5, line of emergence of the ventral roots of the spinal nerves; 6, ventral column; 7, ventral (mesal) fissure; 8, myelocele; 9, dorsal (mesal) fissure; 10, *funiculus gracilis*, the oblongatal continuation of the myelic dorsomesal ("posterior median") column, enlarging cephalad into the clava; the clava and funiculus together are sometimes called "posterior pyramid"; 11, "posterior median fissure"; 12, *funiculus cuneatus*; 13, the shaded band represents the mesal portion of the metacele (caudal part of the "fourth ventricle") between the restes ("restiform bodies") of the two sides; 14, acoustic tubercle, over which run the acoustic striæ, which are not shown; 15, tubercle of Rolando, the continuation of the unspecified funiculus of Rolando, interpolated between the *funiculus cuneatus* and the emergence line of the dorsal roots.

Defects.—Although good in general form and showing the oliva and its arciform fibres (2) with unusual distinctness, the specimen does not exhibit the several columns very clearly, and the lines of demarcation, excepting the "posterior median fissure," are taken from other preparations and from figures; this applies also to the lines upon the pons indicating the passage of the caudal fasciculi entad of the cephalic. The dotted lines demarcating the sectional areas of the peduncles are only approximately accurate. The facial and acoustic nerves are not shown, or the acoustic striæ (see Fig. 693).

C. The lapping of the cephalic portion of the pons over the caudal, giving the appearance of a twist or rotation of the medipeduncle upon its own axis to the extent of the fourth of a circle.

D. The relation to the oliva of the arciform fibres (2), which appear to be derived from the pyramid and to pass around the caudal end of the oliva to enter into the composition of the restis and postpeduncle.

E. The projection of the right clava beyond the left, a marked lack of symmetry in this specimen.

F. The ripa, or line of demarcation between the general, pial surface of the myel and oblongata, and the endymal, metacelian surface. The ripa consists of the pia and endyma with, in some specimens (Fig. 702), a thin intervening lamina of nervous substance.

G. The prepeduncular fossa, a shallow depression on the dorso-lateral surface of the prepeduncle, near the medipeduncle.

§ 86. The visible longitudinal divisions of the postoblongata do not correspond altogether with the myelic columns. The ventral column (Fig. 672, *i*, Fig. 689, *ca*, Fig. 692, 6) continues cephalad partly in the pyramid of the same side, as would naturally be expected, but mostly dips entad of the pyramid and oliva and forms longitudinal fasciculi near the meson farther dorsad.

§ 87. Of the lateral column (Fig. 689, *cl*, and Fig. 692, I) a large part crosses at the decussation (shown in Fig. 689, but not always visible) to constitute mainly the pyramid of the opposite side. Some of the fibres join the restis of the same side, constituting the "direct lateral cerebellar tract." The rest of the lateral column dips entad of the oliva and "forms the longitudinal fibres of the *substantia reticularis grisea*."

§ 88. The dorsal column of the larger portion of the myel is displaced in the cervical region by the dorsomesal ("posterior median") column (Fig. 692, 10); this, in the postoblongata, is called *funiculus gracilis.* Near the apex of the metacele it presents a distinct enlargement, the clava (Fig. 692), cephalad of which the funiculus is no longer distinct. Between the *funiculus gracilis* and the lateral column (Fig. 692, 4) there intervene, in the postoblongata, two funiculi, of which the more lateral (15) is regarded as the direct continuation of the dorsal column of the myel, but is commonly called funiculus of Rolando, sometimes "lateral cuneate"; between it and the dorso-mesal column (*funiculus gracilis*) intervenes another interpolated funiculus, the cuneate (12); this and the funiculus of Rolando appear to enter into the composition of the restis ("restiform body") which is continued as the postpeduncle into the cerebellum; but, according to *Quain*, this relation is rather apparent than real, the components of the restis and postpeduncle being (*a*) the arciform fibres (Fig. 692, 2) from the ventral column, and (*b*) the "direct cerebellar tract" of the lateral column.

§ 89. The increased bulk of the postoblongata is due also in part to the entrance (or exit) of the roots of the accessory, hypoglossal, vagus, and glosso-pharyngeal nerves, which are more numerous than the spinal nerve roots upon a similar length of the myel (see Figs. 672 and 689).

§ 90. *Fig. 693 illustrates:* A. The general topographic relation of the cerebellum to the segments just cephalad and caudad, and to the ventral portion of its own segment, through the three pairs of peduncles, prepeduncle (5), postpeduncle (3), and medipeduncle (the cut area crossed by line 5 on the right and by lines 3, 4, and 5 on the left).

B. The tendency of anatomical writers to ignore the existence or traces or morphological significance of the thin or membranous portions of the encephalic parietes (see my paper, 1891, *b*).

IV. EPENCEPHAL.—§ 91. *Synonyms.*—Epencephalon; metencephalon; cerebellar segment; hindbrain.

§ 92. *Principal Parts.*—Floor: preoblongata and pons. Roof: cerebellum and lingula. Sides: peduncles. Cavity: epicele with lateral recesses. Ectocinerea: cortex. Entocinerea: dentatum, fastigatum, embolus, globulus. Chief cerebellar divisions: (mesal) vermis: (lateral) pileums ("hemispheres"). Flocculus and paraflocculus.

§ 93. *Boundaries.*—The epencephal may be defined as including as much of the brain tube as intervenes between the membranous portion of the roof (metatela) and the decussation of the trochlearis nerve, together with the corresponding regions of the floor and sides and the encompassed cavity, the epicele.

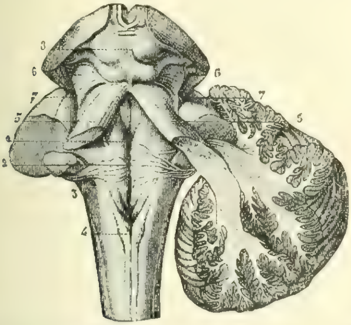


FIG. 693.—Dissection of the Peduncles. × 0.5. (From Quain, after Sappey, and Hirschfeld and Leveillé.) 1, Mesal sulcus; the line crosses the middle of the wide cut surface of the medipeduncle; 2, mesal sulcus at the place of emergence of the acoustic striæ; 3, postpeduncle, continuous with the restis; the cut end of the postpeduncle is crossed by the line, 2; 4, the clava, the swollen portion of the funiculus gracilis; 5, prepeduncle; 6, lemniscus; 7, lateral sulcus of the crus; 8, pregeminum, the postgeminum just caudad.

Preparation.—On the left, the three peduncles are cut short; the right half of the cerebellum is cut obliquely, and tilted laterad, so as to show the connections of the prepeduncle and postpeduncle.

Defects.—There is no evidence of the lines of division, ripas, of the endyma in exposing the metepicele ("fourth ventricle"), or of the existence of the valvula and lingula between the prepeduncles.

§ 94. *Fig. 694 illustrates:* A. The general aspect of the adult cerebellum from the side.

B. The location of three main sulci, furcal, cacuminal, and peduncular.

§ 95. *Epicele.*—The epencephalic cavity includes the cephalic ("anterior") portion of the "fourth ventricle" together with its dorsal extension (fastigium) into the cerebellum, more or less triangular in form. According to Blake (1898–1900, 89–90) the cavity of the cerebellum has at first a greater dorso-ventral extension which is reduced by the fusion of the opposed walls.

§ 96. *Lateral Recesses.*—By this name are commonly known the pair of extensions of the "fourth ventricle" laterad and ventrad (Figs. 684, 695, and 698). Their walls are partly membranous (metatela) and partly substantial (sides of oblongata, peduncles of flocculus, and certain nerve roots). They might with equal appropriateness, perhaps, be described under the metencephal, and the difficulty in determining the segmental assignment is very naturally included by Blake (1898, 104) among the reasons for the non-recognition of two segments in this region.

§ 97. *Fig. 695 illustrates:* A. The embryonic continuity of the endyma and more substantial elements of the parietes around the lateral recesses at this stage (see § 98).

B. The corrugation of the thin portion of the parepicelian parietes preparatory to the formation of the epiplexus.

§ 98. *Outlets of the Lateral Recesses.*—Although closed in the embryo (Fig. 695) the ventral ends of the recesses are commonly described as open, constituting communications with the subarachnoid space even when the metapore does not exist. I have been disposed to regard these orifices as artifacts from the readiness with which the membranous adhesions of that region are torn during the removal and examination of the brain according to customary methods. But the histological and embryological researches of Blake seem to show that in man and in mammals generally the ends of the recesses are opened by the more or less extensive disappearance of the membranous parietes.

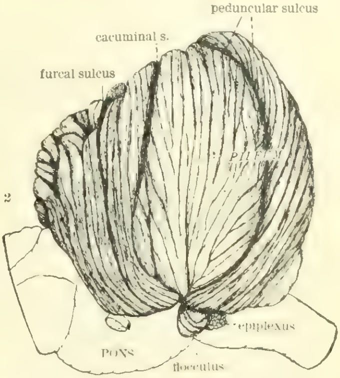


FIG. 694.—Left Side of the Cerebellum of an Aged White Man; 3,434. × 1. (From Stroud, 1897, *a*.) The outlines were drawn with the camera lucida.

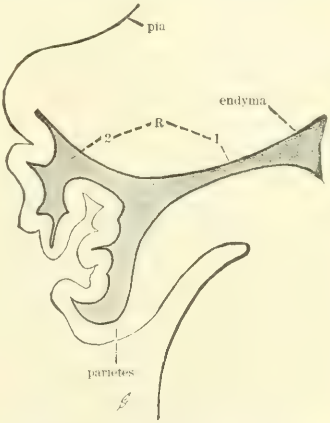


FIG. 695.—Transection of the Brain of an Embryo Rabbit, Sixteen Days Old. (From Kölliker.) × 65; enlargement of part of Fig. 6[illegible]

§ 99. *Fig. 696 illustrates, in addition to points also shown in Fig. 694:* A. The great depth of the furcal sulcus.

B. The absence of the lingular foliums (§ 119).

§ 100. *Preoblongata.*—The floor of the epicele is the preoblongata, continuous with the postoblongata and with the crura. In the turtle (Fig. 680) and other non-mammals there is no obvious line of demarcation.

§ 101. *Pons.*—In mammals the preoblongata is so markedly reinforced by a transverse fibrous mass, the pons, that it is easily recognized; but the width of the pons varies so greatly that its margins can hardly be accepted as the boundaries of the entire segment. Compare the turtle (Fig. 680) with the sheep (Fig. 794) and man (Figs. 672 and 689).

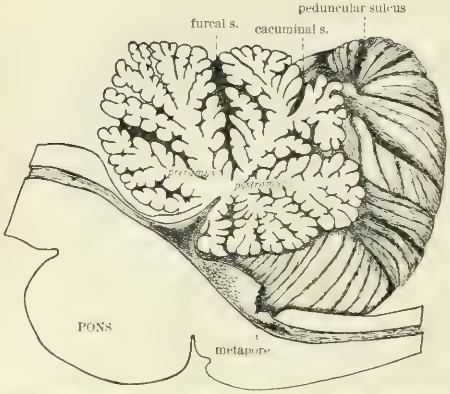


FIG. 696.—Mesal Aspect of the Cerebellum of an Adult Male Negro; 3,118. × 1. Traced from a photograph. (From Stroud, 1897, a.)

§ 102. *Peduncles.*—At and near the meson the connections of the cerebellum with the adjoining segments are thin; the lingula is relatively atrophied (Fig. 702) and the metatela wholly membranous (Figs. 670 and 687); but laterally the cerebellum has massive continuations, constituting three pairs of peduncles: a cephalic (prepeduncles) to the mesencephal; a caudal (postpeduncles) to the metencephal and myel, and an intermediate (medipeduncles) to the pons, part of the same segment.

§ 103. The peduncles constitute a continuous mass of alba at either side, but their relative positions and extent are pretty well determined by various methods, anatomical, microscopical, and experimental. The medipeduncle is the largest and most lateral; it is mainly continued from the lateral lobe of the cerebellum to the pons, where the fibres cross the meson, interdigitating with their opposites, and forming a relation with the cinerea. The postpeduncle mainly connects the vermis with the restis, while the prepeduncle connects chiefly the dentatum with the mesencephal and parts farther cephalad. The dorso-lateral aspect of the prepeduncle presents a distinct shallow depression, the prepeduncular fossa (Fig. 692).

§ 104. The relative location and direction of the three peduncles on the right side may be illustrated by the digits of the right hand. Hold the hand with the fingers down, the thumb pointing backward, the index forward, and the other three fingers, slightly overlapping, outward between them. The palm may then represent the cerebellum, the pollex the short and sharply curved postpeduncle, the index the longer and less curved prepeduncle, and the other three fingers the intermediate and thickest medipeduncle, continuous with its opposite through the pons.

§ 105. *Fig. 697 illustrates:* A. The lapping of the tonsillæ over the uvula.

B. The location of the flocculus and the commencement of the peduncular sulcus.

C. The relative position and size of the three peduncles.

§ 106. *Flocculus and Paraflocculus.*—Attached to the medipeduncle by short peduncles of their own are small foliated masses, the flocculus (in two lobes) and the paraflocculus (in one) (Figs. 698 and 701). Contrary to the implication of the names, the paraflocculus is really attached mesad of the flocculus; in Fig. 698 they are twisted so that the reverse appears to be the case. The peduncle of the flocculus forms part of the wall of the "lateral recess" (Fig. 698). Little is known of the functions of these parts or of their homologues in other animals. According to Stroud (p. 96) the paraflocculus is much larger in the cat and capable of division into a supraflocculus and mediflocculus.

§ 107. *Fig. 698 illustrates:* A. The location and form of the flocculus, with its two divisions and rounded folia, and of the smaller paraflocculus, presenting but slight traces of foliation. All are attached to the medipeduncle, and the flocculus is sometimes called the peduncular lobe.

B. The general location of the lateral recess (2), or parepicele, between the peduncles cephalad, the restis and other parts of the postoblongata mesad, and the flocculus stem laterad; its peculiar relations with the glosso-pharyngeal and vagus nerves are inadequately shown and need special preparation and study.

C. The twisting of the peduncles of the flocculus and paraflocculus whereby their real attachments are apparently reversed. The paraflocculus, although its name

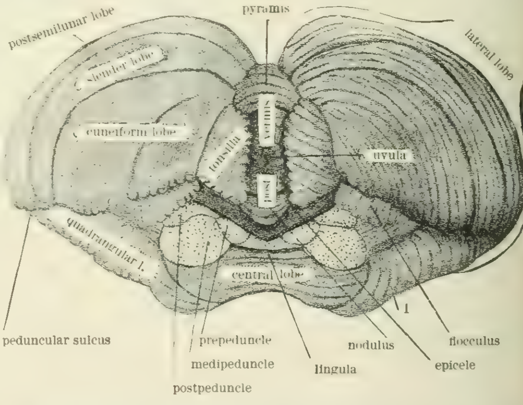


FIG. 697.—Caudal ("Lower" or "Posterior") Aspect of the Adult Cerebellum. A little less than natural size. (From Edinger, inverted and slightly modified.) 1, Part of the right quadrangular lobe. The cut ends of the peduncles are dotted; the large medipeduncles extend latero-dorsad into the lateral lobes; the flocculi are attached to the medipeduncles. The continuity of the vermian divisions with those of the lateral lobes is not apparent upon this aspect.

Defects.—In addition to the general remark made under Fig. 700 the following special deficiencies are to be noted: (1), There is no line to represent the divided endyma of the metatela along the caudal (here upper) side of the cavity (epicele); all this region requires elucidation in respect to celian circumscription; (2), the omission of the plexuses and nerve roots; (3), the postvermis should be more deeply shaded to indicate its depth below the level of the tonsillæ, which also are really almost in contact; (4), on this, or on Fig. 700, the vermis should present a line indicating the reflexion of the arachnoid.

suggests a lateral position, really is attached mesad of the flocculus; see Fig. 701.

§ 108. The *cerebellum* is essentially an arch over the epicele (cephalic part of the "fourth ventricle") (Fig. 699). This condition exists in the embryo, and persists in many of the lower vertebrates. The adult human organ, however, is a foliated mass of complex fibrous and cellular structure, well meriting the adjective *hypertrophied*, applied to it by E. C. Spitzka.

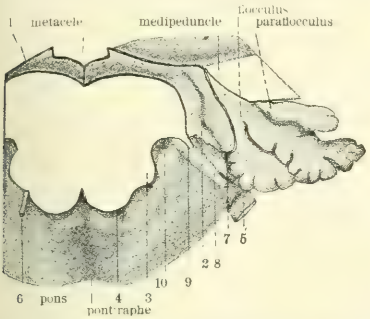


FIG. 698.—Caudal Aspect of the Right Flocculus and Adjacent Parts; 2,238. × 2. 1, Endyma at the left side of the epicele; 2, right lateral recess, laid open; 3, oliva; 4, pyramid; 5, trifacial nerve; 6, abducens; 7, facial; 8, acoustic; 9, glosso-pharyngeal; 10, recess latero-dorsad of oliva.

Preparation.—The cerebellum was removed by division of the peduncles to near the floor of the epicele, and the postoblongata by a transection just caudad of the pons; the lateral recess (2) had already been torn open, as usual, in removing the brain, and its entire extent and exact form are not determinable from this preparation (see Fig. 684).

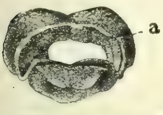


FIG. 699.—Caudal Aspect of the Cerebellum and Oblongata of a Fetus. (Size and age and magnification uncertain, specimen and notes having been lost; it probably resembled quite nearly the specimen shown in Fig. 373.) *a*, The kilos.

§ 109. *Fig. 699 illustrates:* A. The large size of the epicele at this period, as compared with the thickness of the parietes.

B. The extensions latero-ventrad constituting the parepiceles or "lateral recesses" (compare Figs. 384 and 395).

C The non-appearance of the mesal lobe, vermis, at this period and the absence of sulci upon the lateral masses, pileums.

D. The continuity of the riparian part, *a*, the kilos ("posterior velum"), along the line of junction of the ectal pia and ental endyma, they not being represented distinctly; if their torn edges were distinct they would constitute the cestus. The cestus and kilos indicate the line of attachment of the metatela.

§ 110. *Aspects of the Cerebellum.*—In the natural condition of the adult brain the rounded margin of the cerebellum demarcates two surfaces looking respectively "upward" and "downward." But in accordance with the general principle of normalization (§ 38) and by analogy with the simpler case of the epiphysis (§ 154) the cerebellum is here regarded as if projecting dorsad at right angles with its supporting portion of the brain-axis, the oblongata (Fig. 702). The two main surfaces become therefore cephalic and caudal, but they are not sharply delimited.

§ 111. *Pileums and Vermis.*—The adult cerebellum comprises a mesal lobe, the *vermis*, and two *lateral* masses, the pileums, commonly called "hemispheres." On the cephalic aspect, the vermis (prevermis) is prominent (Fig. 700); but on the caudal the lateral lobes project decidedly beyond the postvermis, the surface of which is thus at the bottom of a deep mesal crevice, the vallis ("vallecula") (Fig. 697).

§ 112. *Foliums, Sulci, and Lobes.*—The entire surface of the adult cerebellum presents numerous lines, for the most part parallel and having a generally transverse direction. These lines represent crevices of greater or less depth, the sulci, and the intervening thin plates are the folia. Certain of the interfoliar crevices are so constant, deep, or distinct as to warrant the recognition of the intervening groups of folia as lobes.

The commonly received division of the two regions of the cerebellum into lobes is indicated upon the figures. I am free to admit, however, that I am by no means fully satisfied therewith.

§ 113. *Fig. 700 illustrates:* A. The natural tilt caudad of the cerebellum, so that its normally cephalic surface looks dorso-cephalad, even when the oblongata is held in the cephalo-caudal plane.

B. The extension of the cerebellum, so as to overhang the postoblongata.

C. The enormous preponderance of the pileums (lateral lobes) over the vermis (mesal lobe) in the adult; compare however, Fig. 699.

D. The slight demarcation between the vermis and pileums on this aspect.

E. The appearance of part of the postsemilunar lobes, and of the peduncular sulcus, both these appearing partly also upon the caudal surface.

F. The connection of the two cacuminal (presemilunar) lobes by means of a single folium, the cacumen.

§ 114. *Cortex* (ectocinerea).—Each folium consists of a central lamina of alba and a covering of cinerea having a peculiar cellular structure; see the article *Histology of the Brain.*

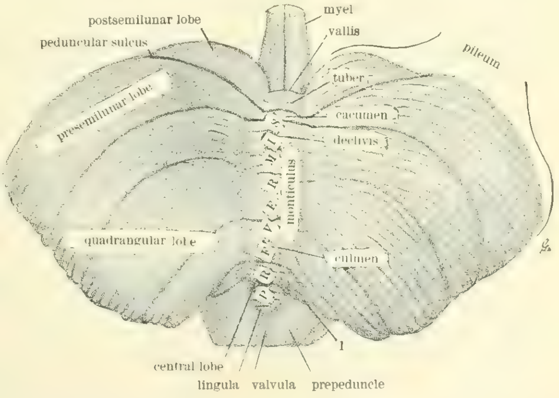
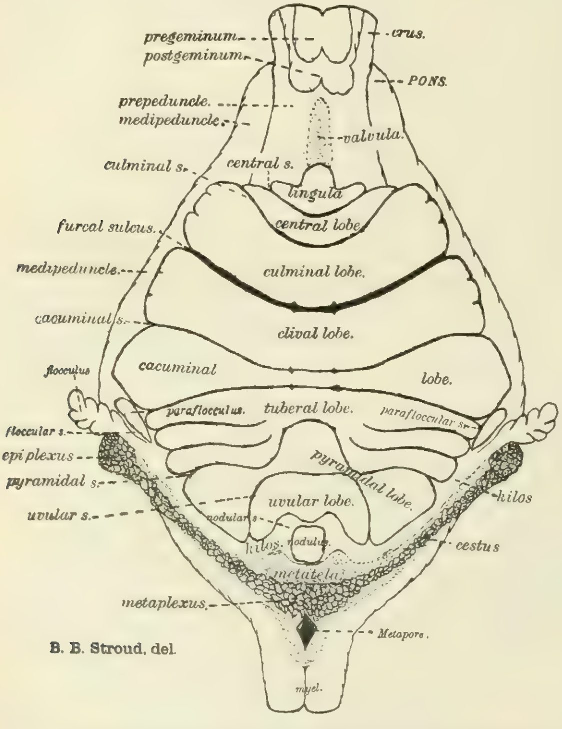


FIG. 700.—Cephalic ("Upper" or "Anterior") Aspect of the Adult Cerebellum. From Edinger, inverted and slightly modified; a little less than natural size. 1, The ala or lateral portion of the central lobe.

Defects.—The original figure is obviously diagrammatic; it was selected as more clear than usual, and as representing the general interpretation of the foliar arrangement on this aspect of the cerebellum; I am not, however, satisfied in all respects, and regret that I cannot determine certain points upon my own preparations, so as to base the figures upon them entirely. These remarks apply equally to Fig. 697.

§ 115. *Peduncular Sulcus* ("*great horizontal fissure*").—When the flocculus and paraflocculus are removed, or the overlapping foliums of the cerebellum are separated from them and from one another by the removal of the pia, the non-foliated lateral surface of the medipeduncle is easily seen to continue laterad and dorsad for about 1 cm. between the tiers of foliums on the cephalic and the caudal aspects. This interval is the beginning or stem of what is commonly called the "great horizontal fissure," but which, from its obvious relation to the medipeduncle, I have called peduncular. By most writers it is represented as continuing along the dorsal ("posterior") margin of the cerebellum and as demarcating the cephalic and caudal aspects of the entire organ. In particular it is regarded as meeting its opposite at the meson just caudad of the cacumen, a single thin folium which, at either side of the meson, enlarges and becomes a subdivided cacuminal ("presemilunar") lobe.

§ 116. *The Peduncular Sulcus Incomplete as a Landmark.*—But, while it is perfectly possible, with most specimens, to recognize a deep sulcus of the pileum which passes caudad of the cacumen and trends laterad in the direction of the medipeduncle, an inspection of the depths arouses doubts of its essential continuity and morphological significance.



B. B. Stroud, del.

FIG. 701.—Diagram Showing the Divisions of the Human Cerebellum as If Extended in One Plane. (From Stroud, 1897, *b*, 108.) The line between the cacuminal lobe and the tuberal lobe should be designated *peduncular sulcus* ("horizontalis magnus").

§ 117. *Furcal Sulcus.*—On various grounds, especially comparative anatomy and development, Stroud has concluded (1897, *a*, 6) that the primary and most constant sulcus, and the one which should be held to demarcate the two main regions of the cerebellum, is one which leaves the stem of the peduncular sulcus opposite the attachment of the paraflocculus and passes at right angles across the cephalic surface, dipping between the adjacent foliums so deeply as to more nearly reach the cavity than any other of the sulci. As seen in Table III. the furcal is the preclival sulcus of Schäfer.

§ 118. The region cephalad of the furcal sulcus is divided by the culminal sulcus (postcentral of Schäfer) into the culminal lobe and the central lobe.

§ 119. *Lingula.*—When the central lobe is lifted or removed there will be exposed the valvula, the thin zone of the mesocelian roof, and caudad of it, completely overhung and concealed by the adjacent parts of the cerebellum, a series of three, four, or five transverse diminutive foliums; see the medisection (Fig. 702). At birth the lingular folia are rounded and distinct, but in the adult they are relatively smaller, often flattened as if by pressure of the overhanging cerebellum, and sometimes (at least in certain negro and insane brains) nearly or completely absent.* The cephalic folium is narrowest and has a rounded outline (Fig. 700): the pia adheres quite firmly to these folia, so that they are liable to be torn off.

§ 120. *Fig. 702 illustrates:* A. The mesal topography of the cerebellum and adjacent parts when brought into nearly their "normal position," *i.e.*, when the metepencephalic floor is nearly horizontal (cephalo-caudal) and when the longer axis of the cerebellum is nearly dorso-ventral; this is nearly their condition in a body lying prone, with the axon and longer portion of the neuron (myel) approximately horizontal, as with most quadrupeds and the majority of walking and swimming vertebrates (see § 9, and the article on *Terminology, Anatomical*). For comparison with Figs. 670, 687, and 756, this or they must be regarded as turned about one-fourth of a circle.

B. The exact number and form of the cerebellar folia and subfolia at birth, so far as they appear upon an approximate medisection.

C. The combination of the folia to form lobes, more or less well defined.

D. The arboriform arrangement, whence the name *arbor vitæ* (herein mononymized to *arbor*).

E. The topographical relations of the mesal lobe (vermis) to the lateral lobes; caudad, dorsad, and at the ventro-cephalic region the lateral lobes project beyond the vermis, but the latter is the more prominent with the culmen at the cephalic side and with the nodulus at the caudo-ventral angle. The interval between the lateral lobes on the caudal aspect constitutes the vallis.

F. The enormous size of the cerebellum as compared with its cavity, even had the dorsal part of the latter been maintained at its natural size by alinjection.

G. The projection of the cerebellum beyond its attachments and proper cavity. Cephalad, it overhangs not only the valvula, but the postgeminum, these being parts of the mesencephal; caudad, whatever exact limit be assigned to the epicele, the vermis covers the entire "fourth ventricle."

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* The lingula has not been recognized in the apes, but Stroud is inclined to regard as its homologue what he described (1897, *b*, 120) as a "cephalic" lobe in apes and in certain human brains, *e.g.*, Fig. 698.

H. The distinctness of the four lingular folia, constituting the transition from the massive cerebellum to the atrophic (?) valvula.

I. The prominence of the cephalic and caudal margins of the pons, and the concomitant depth of the prepontile and postpontile recesses.

J. The merging of the dorsal commissure of the myel and postoblongata into the obex, and of this into the ligula; in the adult this latter seems to be hardly more than the combined pia and endyma (see Fig. 692), but in the child's brain from which this feature was derived, although the meninges had been removed, there was, nevertheless, a distinct lamina of nervous substance.

§ 121. The divisions of the caudal region of the cerebellum cannot be seen completely unless the postoblongata is forcibly bent ventrad or cut away; indeed the entire oblongata and pons may advantageously be removed by transection of the peduncles ventrad of the flocculi as in Fig. 697.

§ 122. When the pileums are divaricated the postvermis caudad of the cacumen is seen to be at first narrow, then wider, and then decidedly compressed. The wide portion is the pyramis; the short region between it and the cacumen, the tuber; the longer portion of the remainder is the uvula crowded between subglobular divisions of the pileums, the tonsils. Finally, and seen with some difficulty, is the nodulus, a group of three or four foliums, connected at either side by the kilos with the flocculus. The relations of these parts to one another and to the lateral masses and to the sulci are indicated upon Table IV.

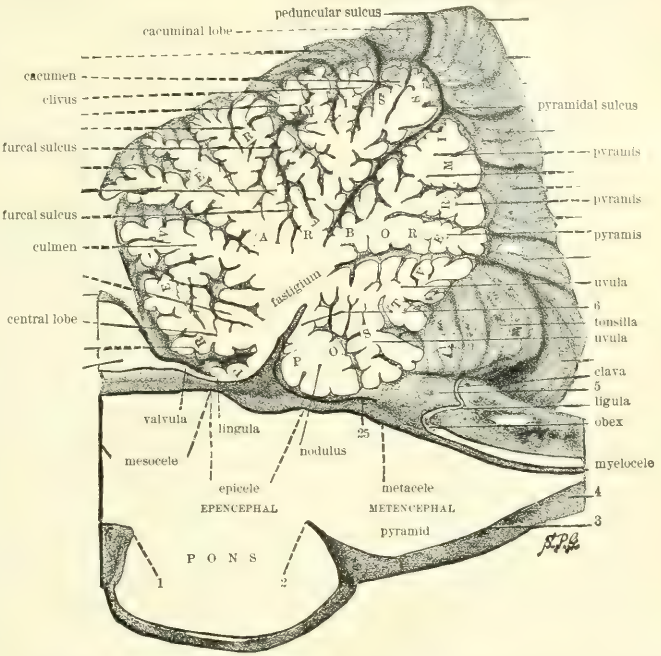

FIG. 702.—The Metepencephal (Cerebellum, Oblongata, and Pons) of a Child at Term, Showing the Approximately Mesal Aspect of the Right Half; 478. × 3. Traced from an enlarged photograph. (This is the same specimen that is shown in Fig. 756, where, however, no attempt was made to represent details, and the cerebellum is more nearly in its "natural attitude." 1, Prepontile recess; 2, postpontile recess (*foramen cæcum*); 3, presumed caudal end of the pyramid; between 3 and 4 there might be but were not seen indications of the pyramid decussation (Figs. 672 and 689); 5, slight elevation of the metacelian floor; the triangular darker area just ventro-cephalad represents the postfovea; 6, the dorsal extension of the epicele into the cerebellum; 25, metatela (diagrammatic).

Defects.—The plane of section passed slightly sinistrad of the meson; hence certain features are not exactly what would have appeared upon a precise medisection. On the cut (unshaded) surfaces the alba and cinerea are not distinguished, the latter having been bleached by the alcohol. The pons section does not show the fibres of the raphé. The cavities were not alinjected and hence are unnaturally small. The meninges were removed; so there is no indication of the dorsal attachment of the arachnoid to limit the subarachnoid space, and the obex, ligula, and metatela are supplied from other specimens, but the extent of the metapore (foramen of Magendie) is not shown.

When the drawing was made, the significance of the furcal sulcus had not been recognized. Dr. Stroud has kindly revised the identifications. He would limit the prevermis to so much as is cephalad of the furcal sulcus; but for the present I retain the original designations of the two regions of the vermis. The sulcus just cephalad of the cacumen is the cacuminal; that just caudad is the peduncular, deep in the pileum (lateral lobe) but shallow at the meson. The tuber is the part between the peduncular and tuberal sulci. See § 120.

TABLE III.—SYNONYMS OF THE PRINCIPAL SULCI OF THE CEREBELLUM; STROUD, 1897, *a*.

Preferred.	Schäfer.
1. Central sulcus.	1. Sulcus precentralis.
2. Culminal sulcus.	2. Sulcus postcentralis.
3. Furcal sulcus.	3. Sulcus preclivalis.
4. Cacuminal sulcus.	4. Sulcus postclivalis.
5. Peduncular sulcus.	5. Sulcus horizontalis magnus. *a*. Sulcus postgracilis. *b*. Sulcus intragracilis.
6. Pyramidal sulcus.	6. Sulcus pregracilis. s. postpyramidalis.
7. Uvular sulcus.	7. Sulcus prepyramidalis.
8. Nodular sulcus.	8. Sulcus postnodularis.

TABLE IV.—SYNONYMS OF THE LOBES OF THE CEREBELLUM; FROM STROUD, 1897, *a*. SLIGHTLY MODIFIED.

TERMS PREFERRED.		SCHAFER.	VARIOUS AUTHORS.
Vermis.	Vermis and pileum.	Worm and hemisphere.	Hemisphere.
		Lobus lingulæ......	Frænulum lingulæ.
1. (Lingula?), Cephalic lobe, *variable*	1. Lingular lobe..	1. Lobus centralis..	Ala lobuli centralis.
2. Central lobe.	2. Central lobe ...	2. *Not recognized as a distinct lobe.*	
3. Culmen..	3. Culminal lobe .	3. Lobus culminis ..	Lobus lunatus anterior.
Furcal sulcus.			
4. Clivus ...	4. Clival lobe.....	4. Lobus clivi	Lobus lunatus posterior.

TABLE IV.—SYNONYMS OF THE LOBES OF THE CEREBELLUM; FROM STROUD, 1897, *a*, SLIGHTLY MODIFIED.—*Continued.*

TERMS PREFERRED.		SCHAFER.	VARIOUS AUTHORS.
Vermis.	Vermis and pileum.	Worm and hemisphere.	Hemisphere.
5. Cacumen	5. Cacuminal lobe	5. Lobus cacuminis.	Lobus postero-superior. Presemilunar lobe.
6. Tuber ...	6. Tuberal lobe...	6. Lobus tuberis....	Postsemilunar lobe. Lobus postero-inferior.
	a. pretuberal lobe.	....	*a*. L. semilunaris inferior.
	b. medituberal lobe.	....	*b*. Slender lobe. L. gracilis posterior.
	c. posttuberal lobe.	....	*c*. L. gracilis anterior.
7. Pyramis..	7. Pyramidal lobe.	7. Lobus pyramidis.	Cuneiform lobe. L. biventralis.
8. Uvula....	8. Uvular lobe....	8. Lobus uvulæ	Tonsilla. Amygdala.
9. Nodulus .	9. The nodulus does not extend laterad into the pileum. The flocculus is a separate division. It is not a part of the pileum (or hemisphere).	9. Lobus noduli.....	Flocculus.

§ 123. *Fig. 703 illustrates:* A. The constitution of the dentatum as a corrugated capsule of cinerea, open cephalo-ventrad.

B. The entrance of the fibres of the prepeduncle through the hilum of the dentatum to connect with its cells.

§ 124. *Entocinerea.*—Upon a medisection of the organ there would appear to be only alba and ectocinerea, the former branching in a tree-like manner, whence the name *arbor (vitæ)*. But in the central part of the cerebellum, near the apex of the epicele, are four pairs of masses of cinerea sometimes called roof-nuclei or tectal nidi. There are reasons for thinking that the primitive cerebellar entocinerea has been displaced, and is represented by these masses enumerated in their order from the meson laterad: Fastigatum; globulus; embolus; dentatum.

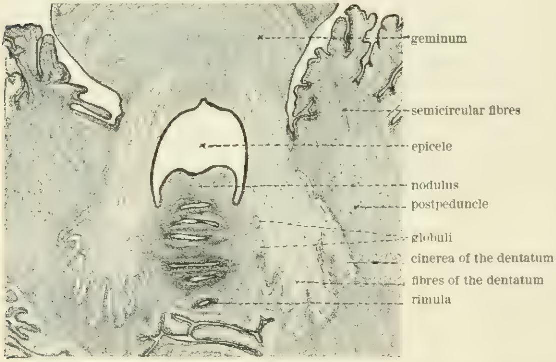

FIG. 703.—The Dentatums and Prepeduncles. (From Stilling, somewhat modified.) × 2 –.
Preparation. The plane of section was oblique, so as to coincide with the general direction of the prepeduncles as shown in Figs. 692 and 693.
Defects.—By an inexcusable oversight the prepeduncles are not indicated by a line and the name; but they are readily recognized as the fibrous tracts at the sides of the epicele, converging from the dentatums to the geminum. There is no representation of the "fleece," the layer of fibres radiating from the ectal surface of the dentatum.

§ 125. *The Dentatum.*—This is the largest and most easily recognized of the four masses; (see Figs. 703 and 704). It has the form of a corrugated capsule, open meso-ventro-cephalad, for the reception of the fibres of the prepeduncle (Fig. 703). In any cerebellum, whether fresh, or hardened in chromic acid compounds, or even alcohol, it is readily recognized upon transections or upon sagittal sections begun about 1 cm. either side of the meson and continued laterad for 2 or 3 cm. The dentatum has received the following additional names, of which the last only is used with any frequency: *Nucleus dentatus; corpus denticulatum, s. fimbriatum, s. lenticulatum, s. ciliare;* Eng., ciliary body.

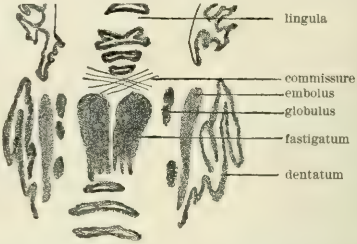

FIG. 704.—The Dentatum and Other Masses of Cinerea in the Central Part of the Cerebellum. From Stilling, somewhat modified. × 2 –.
Preparation.—This is commonly designated as a "horizontal" section. Really, the plane cannot be indicated in such simple terms. The central part of the figure, including the cinereal masses, is through the fastigium, the roof of the apex of the epicele.
Defects.—No attempt has been made to represent the fibrous constitution beyond the purely diagrammatic indication of the cephalic (anterior) decussating commissure.

§ 126. *The Fastigatum.*—This, more often called "fastigial nucleus," is close to the meson, directly in the roof (fastigium) of the epicele; Fig. 703. It is rounded cephalad, but the caudal end presents two or three projections.

§ 127. *The Embolus* and *Globulus.*—These smaller masses of cinerea lie between the dentatum and the fastigium, and somewhat dorsad of the latter. Their forms are indicated by their names, and are well shown in Stilling's figure as reproduced in Fig. 704. More common (and cumbersome) titles are *nucleus globosus* or *globuliformis*, and *nucleus emboliformis.*

§ 128. *Fig. 704 illustrates:* A. The existence, near the apex of the epicele, of four pair of cinereal masses, representing, perhaps, dislocated portions of the cerebellar entocinerea.

B. The lack of precise symmetry in the forms of these masses; of the globuli there are three on the left and two on the right, the more cephalic probably representing two.

V. MESENCEPHAL.—§ 129. Synonyms: Mesencephalon; midbrain. Tabular arrangement of parts: Chief parts: quadrigeminum and crura. Cavity: mesocele (aqueduct or iter.) Floor: crura. Sides: gemina. Roof: gemina and valvula. Ectocinerea: cappa. Entocinerea ("central tubular gray"). Commissures: postcommissure, trochlear decussation.

§ 130. In early embryonic stages the mesencephal is the most conspicuous region of the entire brain, but consists of a single, thin-walled vesicle, with a relatively large cavity (Figs. 671 and 677). As the parietes thicken, two furrows appear upon the dorsal aspect; a mesal, demarcating the left elevation from the right, and a transverse, subdividing each of these into a cephalic and a caudal portion (Fig. 673); there results, in the adult mammalian brain, the formation of four approximately similar elevations, whence the names, *corpus quadrigeminum, corpora quadrigemina, optic lobes*, etc. In the present article they are called *gemina* (twin bodies), pregeminum and postgeminum (Figs. 693 and 707). They constitute the larger part of the mesocelian roof.

§ 131. *Valvula.*—A caudal portion of the mesocelian roof retains nearly its primitive tenuity as a transparent lamina, the valvula, between the gemina and the lingula (Fig. 702). Its cephalic part presents some slight corrugations, either a mesal furrow and a pair of lateral ridges, the frenulums (Fig. 706), or a mesal ridge in addition.

§ 132. The fibres of the trochlearis nerve decussate in the valvula. It is practically convenient, although not perhaps quite correct, to regard the trochlear decussation as the boundary between the mesocelian valvula and the epicelian lingula (see Fig. 675).

§ 133. *Mesocele.*—In all mammals what Tiedemann picturesquely described as a "vast and spacious cavity" becomes relatively an insignificant tubular passage, which has been called "aqueduct" and *iter a tertio ad quartum ventriculum.* As may be seen from Figs. 670, 687 and 756, it is expanded or trumpet-shaped at the cephalic end, and irregular in form at the caudal; the intermediate, longer part varies considerably in different individuals, being sometimes nearly cylindrical, but usually a transection presents points in two, three, or four directions, lateral, ventral, dorsal; the departures from the cylindrical shape are more frequent and distinct in the postgeminal and valvular portion (see Figs. 687, 706, and 708), and may be regarded as vestiges or suggestions of the potentially tripartite condition which is actually present with birds and frogs (Fig. 685).

§ 134. *Lemniscus and Brachia.*—The lateral slope of the mesencephal presents three megascopic features, the lemniscus, postbrachium, and prebrachium, shown in Fig. 706; in the former the fibres run approximately cephalo-dorsad, in the latter obliquely dorso-ventrad; their course and connections are considered in the article *Brain, Histology of the*, as is also the extent of the ectocinereal lamina called *cappa.* The lemniscus and its connections have been discussed at considerable length by E. C. Spitzka, 1884, *c.*

§ 135. *Entocinerea.*—This is the least modified of all portions of the encephalic "central tubular gray"; it forms a layer 2 to 3 mm. thick surrounding the mesocele.

§ 136. *The Crura* (*crura* or *pedunculi cerebri*).—Excepting the parts already named, the mesencephal consists mainly of a pair of fibrous masses (Figs. 672 and 689) containing the compacted motor and sensory conductors between the regions caudad, whose relations are mainly with the body, and the regions cephalad, which are the organs of the mind. Each crus consists of two regions, a ventral, the crusta, and a dorsal, the tegmentum (Figs. 706 and 708).

§ 137. *Intercalatum* (*substantia nigra, locus niger*).—A transection through the crus at almost any level reveals a dark mass (Figs. 706 and 708) of crescentic outline, approximately dividing the section into a ventral third and a dorsal two-thirds. Its lateral and mesal borders correspond to the furrows called *sulcus lateralis* and *s. oculomotorius.* The name commonly employed refers to the distinctly dark color (due to pigment in the cells) of the mass in man and some apes; but the absence of color in other mammals has led E. C. Spitzka to propose a name referring to its more constant character of *intercalation* between the ventral crusta and the dorsal tegmentum; the locative mononym was adopted by the Association of American Anatomists in 1897.

§ 138. *Postcommissure.*—The cephalic margin of the mesocelian roof is of moderate thickness, and curved dorsad so sharply as to present a cephalic convexity (Fig. 705) and a caudal concavity (Fig. 687). Osborn has suggested that it is intersegmental like the trochlear decussation (Fig. 675).

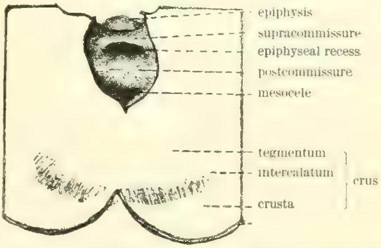

FIG. 705. The Postcommissure and Adjacent Parts; 2,239. × 1.5.
Preparation. The diencephal was transected just cephalad of the postcommissure; the diatela was torn away to admit more light; the space just above the epiphysis was occupied by the dorsal sack. The figure should be compared with the medisections (Figs. 670 and 687), and with the dorsal aspect of the region (Figs. 707 and 708).

§ 139. *Fig. 705 illustrates:* A. The appearance of this aspect of the postcommissure as a cylinder.

B. The considerable size of the epiphyseal recess; although a mere diverticulum within an apparently functionless organ, it is larger than the cephalic orifice of the mesocele in this specimen.

C. The distinctness of the supracommissure (*commissura habenarum*).

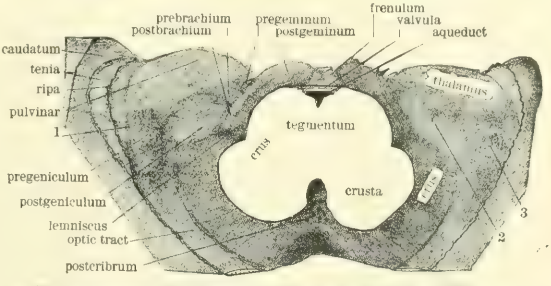

FIG. 706.—Caudal Aspect of the Mesencephal and Part of the Diencephal; 2,360. × 1.5. 1, Tenial sulcus; 2, right postgeniculum; 3, right pregeniculum.
Preparation. A well-hardened, alcoholic, adult brain was transected just cephalad of the pons, at a level indicated nearly by the line from *crus* in Fig. 707. A block containing the thalami and adjacent parts was then cut out by incisions in various directions, the fornix peeled off, and the velum and other parts of the pia removed; the ink lines near the sides marked *ripa* indicate the lines along which the lateral margins of the velum, the paraplexuses, were torn away.
Defects.—More should have been left at the sides and ventrad. On the left, the roughly indicated curved line just laterad of the tenia was due to inadvertence, and may be disregarded. See § 140.

D. The location of the dorsal sac upon (morphologically, cephalad of) the epiphysis; see Fig. 687.

E. The modified relative position of these parts. In a less modified condition of things, the two commissures and the epiphysis should all lie nearly in one plane; but the pressure of the superincumbent cerebrum has made the long axis of the epiphysis cephalo-caudal instead of dorso-ventral, and left the two commissures and the two orifices in a dorso-ventral series instead of a cephalo-caudal.

§ 140. *Fig. 706 illustrates:* A. Segmental overlapping. The thalami and geniculums project caudad beyond the intersegmental line, and the caudatum is here directly laterad of the thalamus instead of cephalad; consequently a transection through the pregeminum would divide not only the mesencephal, but also both the diencephal and the prosencephal.

B. The caudal extension of the thalamus as a rounded eminence, the pulvinar, on which, at the right, the word *thalamus* is placed.

C. The existence of two other eminences on this aspect of the diencephal, the postgeniculum, mesad and more distinct, and the pregeniculum, laterad and less distinct. With lower mammals the general mass of the thalamus is less developed than in man, and the pregeniculum is not only still less prominent, but also decidedly cephalad, so that the prefixes *pre* and *post* are much more appropriate.

D. The continuity of the optic tract with both the geniculums, more obviously with the pregeniculum.

E. The nearly complete concealment of the pregeminum, in this view of the parts, by the postgeminum; the former is seen at the left to project slightly.

F. The location and forms of the postbrachium and prebrachium; the former is between the two geminums, the latter just cephalad of the pregeminum; as they pass ventrad they embrace, as it were, the postgeniculum.

G. The location of the lemniscus, just caudad of the postbrachium.

H. The **T**-shape of the mesocele in this specimen.

I. The thinness of the mesocelian roof, here constituted by the valvula, with a mesal furrow and lateral ridges, the frenulums.

J. The relatively extreme thickness of the mesocelian floor, constituted by the crura.

K. The division of each crus into a ventral crusta and a dorsal tegmentum, the boundary between these two regions being defined partly by the lateral furrow, opposite the word *crus*, on the left, and partly by a pigmented tract, the intercalatum, not here seen, but shown in Figs. 705 and 708.

L. The deep ventral depression between the crura, constituting an intercrural area.

M. The presence, at the cephalic end of this area, of several rather large foramina for the transmission of arterial branches, whence this part is called postcribrum ("posterior perforated space").

N. The trefoil outline of the mesencephalic transection due to the mesal and the two lateral depressions.

O. The obviously and unquestionably pial and ectocelian character of all the natural mesocelian surfaces.

P. The equally unquestionable continuity of these surfaces over the geniculums to the pulvinar.

Q. The absence of anything like a ripa on the visible surface of the thalamus until we reach the sharp and irregular line so marked at the left.

R. The endymal and entocelian character of the slender natural surface of the caudatum.

S. The continuation of this endymal surface upon the visible length of the tenia.

T. The significance of the ripa as not only a boundary between contiguous pial and endymal surfaces, but as indicating where the margin of the paraplexus or some membranous continuation of it has been torn away.

§ 141. *Fig. 707 illustrates:* A. The segmental overlapping of the diencephal at the side of the mesencephal and of the prosencephal at the side of that (see § 55).

B. The division of the caudatum (the entocelian portion of the striatum) into a cephalic, enlarged *caput* and a caudal, slender *cauda*.

C. The unlike topographical relations of these two parts, in that the caput is uncomplicated, while the cauda has a slender, marginal (riparian) band at its mesal side, the tenia, having peculiar relations with other parts.

D. The location of the diacele between the two thalam and its continuity with the aula.

E. The presence of the medicommissure (seen somewhat better in Fig. 709).

F. The relation of the callosal genu to the intercerebral fissure and the pseudocele; but for the callosum the fissure and the pseudocele would be continuous, as would also the hemiseptum with the general mesal wall of the precornu.

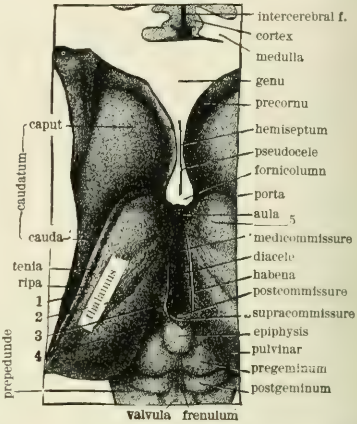

FIG. 707.—Dorsal Surfaces of the Caudatum, Thalamus, and Gemina. (From Henle, reduced and slightly modified.) 1, Tenial sulcus; 2, fimbrial sulcus; 3, habenal sulcus; 4, trigonum; 5, "anterior tubercle" of the thalamus.

Preparation.—The dorsal portion of the cerebrum has been removed, including the callosum, fornix, velum, paraplexuses, and diatela; also the pia covering the epiphysis and mesencephal.

Defects.—The shading is too deep and does not indicate the distinction between the pial and the endymal surfaces. The caudal parts of the thalami are crowded mesad, and the gemina are not well shaped.

G. The demarcation of the mesal, entocelian surface of the thalamus from the dorsal, entocelian surface by a rough edge just dorsad of the habena; here it is represented by the narrow, white line between the two black ones, and designated as the habena; it is really a ripa along the dorsal side of the habena (see also Figs. 687 and 739).

H. The presence of three shallow furrows on the dorsal surface of the thalamus; a dorso-mesal, just dorsad of the habena, the habenal sulcus; a lateral, corresponding nearly with the mesal edge of the tenia, the tenial sulcus; an intermediate and oblique, corresponding with the lateral margin of the fimbria (removed), the fimbrial sulcus.

I. The demarcation of the dorsal surface of the thalamus, which is pial and ectocelian, from the adjoining surface of the caudatum and tenia, which is endymal and entocelian, by a sharp, irregular line at the mesal edge of the tenia, constituting a ripa. This line was introduced into the figure; it is absent in the original, as in all similar figures known to the writer, excepting Fig. 16, in Meynert's "Psychiatry," where it is called "*linea aspera*," without, however, any reference to its morphological significance.

J. The vague and unsatisfactory representation of the parts at the porta. This region has yet to be cleared up in respect to the relation of the pial and endymal surfaces; it was my inability to show these relations clearly upon original preparations that led me to employ the present figure provisionally.

K. Incidentally it may be remarked that both this and the previous figure exemplify the advantages of that feature of the simplified nomenclature which consists in the designation of members of natural or artificial groups of parts by words compounded of the generic terms and prefixes indicating relative position; *e.g.*, pregeminum and postgeminum; pregeniculum and postgeniculum; precommissure, medicommissure, postcommissure, and supracommissure.

V. DIENCEPHAL.—§ 142.—Synonyms: Diencephalon, deutencephalon, thalamencephalon, interbrain, 'tweenbrain. Tabular arrangement of parts: Chief parts: thalami. Cavity: diacele. Floor: tuber, chiasma, and diaterma. Sides: thalami. Roof: diatela (practically the velum). Plexuses: diaplexuses. Commissures and decussations: medicommissure, supracommissure, chiasma. Ectal elevations: albicantia, pregeniculums, and postgeniculums. Perforated areas: precribrums and postcribrum. Ental elevations: habena. Ectal depressions: trigonum, habenal, tenial, and fimbrial sulci. Ental depression: aulix ("sulcus of Monro"). Appendages: hypophysis, epiphysis, and dorsal sac.

With the adult of man and all other mammals the primitively thin sides of the diencephal are greatly thickened and become the *thalami*, with the *geniculums* (pre- and post-) as latero-caudal elevations. The relations of the diencephal to the entire brain are well indicated in the young rabbit (Fig. 681).

§ 143. The *pregeniculum* and *postgeniculum* are represented in Figs. 706 and 707, and described in connection therewith; the *optic tract* and the *chiasma* are shown in Figs. 689 and 711, and considered in connection with the optic nerves in the article, *Cranial Nerves.*

§ 144. *Fig. 708 illustrates:* A. The form, direction, and complete separation of the albicantia; they are usually represented (as in Figs. 672 and 689) as hemispherical elevations; here they are seen to be elliptical in outline, their longer axes converging caudad, and the caudal ends overhanging the postcribrum; in the sheep (Fig. 794) and in mammals generally the albicantial sulcus is a shallow depression or wholly absent.

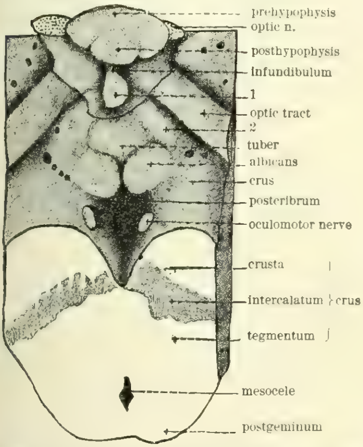

FIG. 708.—The Tuber (*tuber cinereum*) and Adjoining Parts; 706. × 1.5. (The same region is shown in Figs. 672 and 689, upon a smaller scale.) 1, Expanded proximal end of the infundibulum, covering the lura, which is exposed in Fig. 672; 2, a slight elevation between the tuber and the optic tract. The irregular line across the tuber and optic tracts represents the cut or torn edge of the pia, which adheres quite firmly to the chiasma. The black spots represent the foramina in the postcribrum and elsewhere through which vessels passed; the triangular region laterad of the chiasma is a part of the precribrum ("anterior perforated space").

Preparation.—The brain was removed with great care, the hypophysis being extricated from its fossa by dividing the dural folds in several directions with the sharp point of a scalpel, and then introducing the blunt-pointed syringotome.

Defects.—The natural surfaces of the crura should have presented a more fibrous appearance (somewhat as in Fig. 689), and another preservative than alcohol would have differentiated the cinerea on the cut surface. The albicantia have perhaps the appearance of overhanging the postcribrum too far, but this is more nearly correct than the usual representation, as, for example, in Figs. 672 and 689. The left intercalatum should be shown more nearly like the right.

B. That the hypophysis is wider than long, and consists of two parts, conveniently called *prehypophysis* and *posthypophysis;* the latter is the smaller and partly as it were let into an emargination of the former.

C. The expanded base of the infundibulum (1).

D. The raised, unnamed area (2) at either side of the tuber.

E. The demarcation of the crusta from the tegmentum by the intercalatum.

F. The slight, angular extensions of the mesocele, which sometimes is almost circular in outline.

§ 145. The diacelian floor is various in direction and composition. Beginning with the mesencephalic floor, the crura (Fig. 687), there is a marked decrease in thickness in the region of the postcribrum (which may really be common to the two segments), as well as a deflection of the floor ventrad; the albicantia (Figs. 672, 689, and 708) constitute lateral thickenings, and then the floor is reduced to an atrophied lamina comparable with the valvula; this, with the shorter, thin part just cephalad of the intervening and dependent hypophysis, constitutes the tuber (*tuber cinereum*) and infundibulum. The fusion of the stems of the primitive optic vesicles to form the chiasma, and the fusion of this with the otherwise thin diacelian floor, confers upon the latter in this region considerable thickness and firmness, but this part is again succeeded by the atrophied terma (Figs. 687 and 711), strictly the diaterma, in distinction from the prosoterma dorsad of the precommissure. Although the diaterma has a nearly dorso-ventral direction, it should properly be regarded as part of the floor, since the aula, the mesal division of the prosocele, is constructively cephalad of the diacele, although actually more nearly dorsad.

§ 146. *Hypophysis* (pituitary body or gland, Figs. 670, 687, and 708).—This has a twofold origin, viz., from the neuron (posthypophysis) and from the enteron (prehypophysis); see the article *Brain, Development of.* Herdman thinks it may have been an ancestral sense organ (*American Naturalist*, 1888, p. 1127). At present, notwithstanding its constancy throughout the vertebrates, its function is still in doubt, but the not infrequent coexistence of acromegaly with lesion of the hypophysis merits careful consideration.*

§ 147. In marked contrast with the massive sides the diacelian roof is, for the most part, very thin, consisting apparently of the endyma only, closely attached to the ventral or diencephalic layer of the velum, from which are developed the parallel diaplexuses (Figs. 716 and 732) dependent at either side. Cephalad, the diatela is continuous with the aulatela, or perhaps directly with the fornix dorsad of the aula and portas; caudad, it extends for some distance beyond the proper diencephalic boundary, is reflected ventrad upon the dorsal (properly cephalic) aspect of the epiphysis to constitute the dorsal sac, and is then continuous with the supracommissure, and the epiphysis itself (Fig. 687).

§ 148. *Fig. 709 illustrates:* A. The size, form, and connections of the medicommissure; it is relatively smaller than in other mammals (Fig. 688), and slightly constricted about its middle; if isolated it would have the form of a pulley-wheel with a shallow groove.

B. The relations of the mesal aula to the portas and to the diacele (see § 163).

C. The thinness of the lamina uniting the two halves (columns) of the fornix. This lamina must be regarded as the primitive prosocelian terma as high as the dorsal limits of the porta, and may, therefore, be called the *prosoterma.*

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* On this subject articles have been published by Woods Hutchinson in the New York *Medical Journal* for July, 1900.

§ 149. *Habena* (habenula); (Fig. 687).—At the dorsal margin of the mesal surface is the *habena*, a slight ridge, with a dorsal convexity, extending from the porta to the supracommissure, which unites it with its opposite.

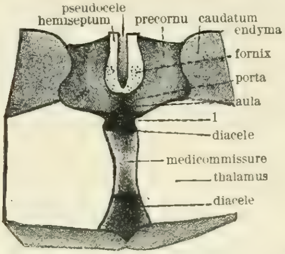

FIG. 709.—The Medicommissure and Adjacent Parts; 2032. × 1.3. (Compare Fig. 707, where some of the same parts are shown on a smaller scale.)

Preparation.—The brain was removed with care so as not to tear the medicommissure, and alcohol was injected *per luam* so as to harden the parietes and keep them apart. The prefrontal lobes were then removed, thus opening the precornua and exposing the caudatums; with these as guides the block containing the medicommissure was safely isolated; the thalami are cut away almost to the level of the commissure. See § 148.

Along the dorsal side of the habena is the habenal sulcus, and the two represent nearly the line of reflection of the endyma from the mesal surface of the thalamus upon the roof of the diacele (see Figs. 681, 687, 707, and 732).

§ 150. *Fig. 710 illustrates:* A. The overlapping of the cerebrum upon the diencephal, so that the transection of one includes the other.

B. The folding of the pia covering the now apposed dorsal surface of the thalami and the ventral surface of the cerebrum so as to constitute the velum (see Fig. 732); but since this figure does not represent the lapping of the prosencephal upon the diencephal at the *sides*, or the formation of the rima and paraplexus, the pia of the two segments is continued independently around each.

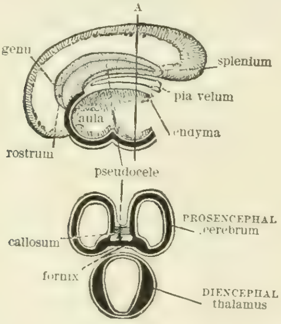

FIG. 710.—Diagrams Illustrating the Relations of the Callosum, Fornix, and the Pseudocele, the Constitution of the Velum, and the Superposition of the Prosencephal. The upper figure represents the mesal aspect of the right half of the schematic brain; the lower, a transection of both right and left halves at the level indicated by the line A in the upper. In the lower figure the thickening of the black line representing the fornix may indicate the hippocamp, but strictly it should be corrugated, presenting an ectal furrow—the hippocampal fissure. The relations of the fornix to the rest of the parietes would also be more completely shown had the black line been interrupted a little laterad of the hippocamps.

Defects.—The aula, the mesal part of the prosocele, is shown of equal size with the diacele, and on the same level; this is not the case, so far as the writer is aware, with any vertebrate in which the callosum and fornix attain dimensions such as are indicated in the figure (see Fig. 725); but so far as concerns the special objects of this figure, the above inconsistency may be ignored. Unlike most of the figures, the substantial nervous parietes are represented by the heavy black line, the pia and endyma by lighter ones.

C. The theoretical constitution of the diacelian roof by (1) the possible, though not always actual, continuation of the thicker nervous material at the sides, (2) the lining endyma, (3) the covering pia, one or both layers according to the closeness of their adhesion.

D. The relations of the callosum, fornix, and pseudocele; the two former represent two lines of extended junction between the apposed mesal surfaces of the hemicerebrums; they are continuous at the splenium and likewise in man at the cephalic end; the space thus circumscribed like the hollow of a partition is the pseudocele or "fifth ventricle"; it is really narrower, but the relations are as indicated.

E. The general constitution of the fornix is more fully described in § 197.

§ 151. *Medicommissure* (commissura media, s. grisea, s. cinerea, s. mollis, s. thalamic fusion).—Primarily separate, the apposed, mesal surfaces of the thalami unite (at about the fifth month of gestation according to Mihalkovics), giving rise to what is commonly called the "middle commissure" (Figs. 670, 687, 707, and 709). It is in a direct line between the porta and the aqueduct, considerably nearer the former, and just dorsad of the aulix. The shorter, dorso-ventral, diameter, is 4–5 mm., the longer, cephalo-caudal, 6–7. It is relatively larger in all other mammals (*e.g.*, sheep, Fig. 688); it is present in turtles (Fig. 680) but absent in birds and other immammalia. Its functions are experimentally unknown, but in a man and a cat lacking the callosum, it was larger than usual.

§ 152. *Anomalies of the Medicommissure.*—It is said to be sometimes double. Among sixty-six brains Wenzel found it absent in ten. It is wanting in at least half a dozen of the (about two hundred) brains prepared or examined by me with reference to it, amongst others in No. 3,334, Professor Oliver.*

§ 153. *Aulix* (sulcus of Monro; part of the interzonal sulcus?).—Most well-preserved brains present a more or less distinct furrow just ventrad of the medicommissure terminating cephalad at the porta ("foramen of Monro") and caudad near the postcommissure, sometimes in the mesocele and sometimes in the epiphyseal recess. It was figured and described by Reichert under the title "sulcus Monroi," for which I proposed (1884, *c*) the mononym *aulix*, a furrow (Figs. 675, 687).†

§ 154. *Epiphysis* (conarium, pineal body or gland; Figs. 675, 687, 707).—Excepting the lancelet (*Branchiostoma*) every vertebrate likewise has this apparently useless or vestigial diverticulum of the diacelian roof. Max Flesch believes that it is associated with the temperature apparatus, but the number of forms in which has been traced a connection between it and a rudimentary mesal eye is so great as apparently to warrant the view that it is the remnant of a primitive mesal organ of vision; see the papers of Béraneck (1892,) Heckscher, Ritter (1891), and Studnička (1899); Ritter also describes the relation of the epiphysis to a blood sinus in *Phrynosoma.*

§ 155. *Acervus (acervulus cerebri).*—The adult epiphysis frequently has embedded in follicular cavities calcareous particles known by the above names, and as "brain-sand"; in the brain shown in Fig. 687, it was so abundant as to leave a considerable cavity when removed, but this unusual feature is not represented.

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* I venture to suggest that some of the reported cases may have been based upon inadequate evidence. Unless the brain is medisected while fresh, or prepared by the injection of a preservative into the arteries or the cavities, or both, the medicommissure commonly fails to be reached; its peculiar softness causes it to break easily; and the imperfect preservation of the adjacent thalamic surfaces might lead to the non-recognition of the slight elevation indicating its existence. If the specimen is allowed to dry slightly, and is then held so that the light is reflected from the smooth endymal surface of the thalamus, then the presence of the remnant of the commissure will be indicated by the absence of such reflection from an area corresponding with its usual location. There are few other parts of the brain where errors of observation are more likely to occur.

† His and others have applied the name "sulcus Monroi" to an alleged sulcus extending from the mesocele to or toward the optic recess, and have interpreted it as a portion of the interzonal sulcus (*sulcus limitans ventriculorum*); the grounds for dissent from this interpretation are stated in my papers 1896, *d*, and 1897, *a*.

§ 156. *Peculiar Topographic Relations of the Epiphysis.*—One of the striking results of the segmental overlapping and crowding is the embedding, as it were, of the epiphysis amongst four segments. Although directly connected with the thalami, the epiphysis leans caudad so as to rest upon the pregeminum; the cephalic aspect of the cerebellum rests upon the postgeminum and abuts against the epiphysis; finally the callosum, a cerebral commissure, has its splenial curvature upon the epiphysis. Between all these parts, of course, there are membranes and vessels, but if they are disregarded the epiphysis, a part of one segment, the diencephal, may be described as encompassed by three others, the mesencephal, the epencephal, and the prosencephal. With a brain hardened in its natural shape, a disc 2 cm. in diameter (*e.g.*, a "nickel") will cover parts of all four encephalic segments; see particularly specimens 385 and 2,268; in drawings, for the sake of clearness, the parts are sometimes represented as if less crowded; *e.g.*, Figs. 672 and 687.

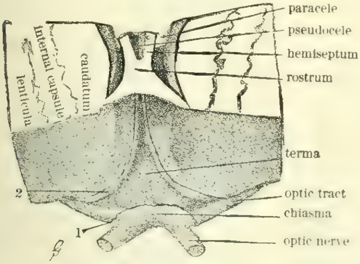

FIG. 711.—Cephalic Aspect of the Terma ("*lamina terminalis*") and Adjacent Parts of a Young Child; 213. × 1.5. 1, Torn margin of the pia on the chiasma; it has been removed from the adjacent surface; 2, gyrus subcallosus, continuous dorsad with the "peduncle of callosum."

Preparation. The brain was exposed by removing the skull with nippers and scissors so as to avoid tearing the terma; the optic nerves were divided close to their foramina of exit. After hardening in alcohol, the parts adjacent to the terma were carved away; the surface at either side is concave, following the general direction of the terma. The block was strengthened by a long (shawl) pin passed from side to side, and a common pin was pushed into the striatum at either side so as to project beyond the optic nerves and keep the latter from striking the sides of the vial. The removal of the pia from the terma was the most difficult part of the preparation, and the utmost care did not prevent the tearing of a small slit in the left side, which is ignored in the figure.

§ 157. *Fig. 711 illustrates:* A. The existence and completeness of the terma (*lamina terminalis* or *l. cinerea*), constituting the cephalic boundary of the mesal encephalic cavities; in the embryo it is actually the most cephalic part of the brain, but is later concealed by the projecting hemicerebrums.

B. The continuity of the terma with the chiasma, leading to the rupture of the former during the removal of the brain unless the optic nerves are early divided.

C. The extreme thinness and delicacy of the terma which cannot be represented adequately in such a view, and is not always indicated in the medisections; Fig. 687.

D. The existence of a somewhat thicker extension of the terma at each side, forming the cephalic boundary of the optic recess.

E. The pair of slightly raised bands, commonly called the "peduncles of the corpus callosum," continuous ventrad with the gyri subcallosi.

F. The convexity of the entocelian surface of the caudatum (see also Fig. 707).

G. The relation of the callosal rostrum to the hemiseptums, the lateral halves of the septum lucidum.

H. The somewhat unusual thickness of the hemiseptums in this specimen.

VII. PROSENCEPHAL. —§ 158. Synonyms· Prosencephalon; telencephalon; forebrain; secondary forebrain; cerebrum;* pallium. The prosencephal is here regarded as composed of the cerebrum (cerebral hemispheres) less the olfactory bulbs and tracts, and the parts and cavities connecting them across the meson. See Table II., p. 153.

§ 159. *Peculiarities of the Prosencephal.*—From the other segments the prosencephal is distinguished by (*a*) the extraordinary range of variation among vertebrates, as seen in, *e.g.*, the hag (Fig. 791), the lamprey (Fig. 790), the salamander (Fig. 717), the frog (Fig. 685); the rabbit (Fig. 681); and cat (Fig. 682); (*b*) its preponderance in the human adult as contrasted with its primary insignificance (Fig. 676); (*c*) its (generally conceded) function as the organ of the "mind."

§ 160. *Prosocele.*—The prosencephalic cavity is primarily single and mesal, as indicated in the diagram, Fig. 674; it may remain so in cyclopean monsters (Fig. 712), and a nearly undivided adult cerebrum has been described by Turner (Fig. 713).

§ 161. *Fig. 712 illustrates:* A. The increase of the prosencephalic vesicle in size and in the thickness of its parietes. As shown in Fig. 2 of the original paper, the floor and cephalic wall of the mesal region are 7 to 11 mm. thick, supposing the parts to be of natural size.

B. The subordination of the lateral extensions to the mesal portion of the prosencephal; they do not, as in the normal brain, extend cephalad of the mesal boundary, but merely laterad, caudad, and to a certain extent ventrad, so as partly to overlap the mesal portion.

C. The partial formation of fissures, one of which may represent the Sylvian.

D. As stated in the text, the prosencephalic cavity is single, *i.e.*, not divided by constricted orifices (portas or "foramina of Monro") into a mesal aula and lateral paraceles. In this respect the cyclopean brain may be compared to the normal brain of "fishes" (Ganoids and Teleosts).

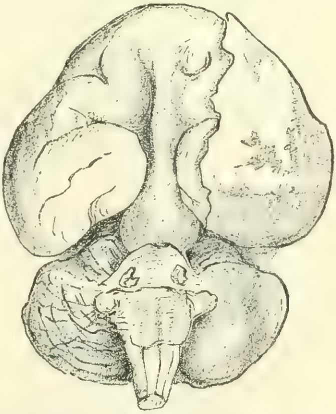

FIG. 712.—Ventral Aspect of the Brain of a Cyclops, at Term. (From Cleland, *Journal of Anatomy and Physiology*, xii., Pl. xvii., Fig. 1.) The size of the specimen is not stated. The arachnoid has been removed from the mesal region, and from the left. The original paper contains a figure of a medisection of the entire mass, a description of some animal cyclopians, and a brief discussion of the nature of the malformation.

E. The morphological instructiveness of many malformations. Goethe well said, "In her mistakes Nature often reveals her secrets"; indeed it is scarcely possible to imagine any encephalic malformation that may not suggest, illustrate, or apparently contravene some morphological idea.*

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* Cerebrum is sometimes employed loosely as embracing not only the olfactory region, but the thalami, quadrigeminum, and crura.

§ 162. *Fig. 713 illustrates:* A. The possibility that an individual should reach maturity with a cerebrum so nearly undivided. Substantially, the prosencephalic vesicle has not only increased in size and in parietal thickness, with but slight differentiation into a mesal and lateral mass, but the entire mass has developed fissures and gyres after the usual pattern, in general, excepting that certain gyres cross the meson; *a priori*, indeed, it is not clear why such a brain should not be efficient for mental as well as bodily manifestations.

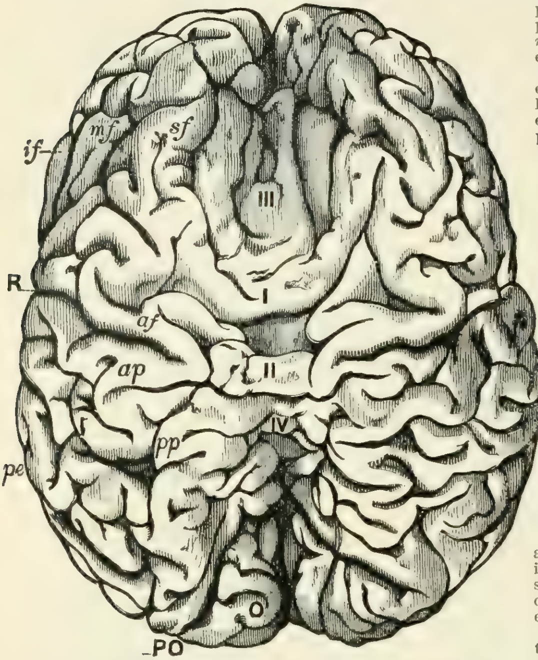

FIG. 713.—Dorsal Aspect of an Imperfectly Divided Cerebrum. × .7. (From Turner, *Journal of Anatomy and Physiology*, xii., January, 1878, pp. 241-253.) *af*, Precentral gyre; *ap*, postcentral gyre; *if*, subfrontal gyre; *mf*, medifrontal gyre; O, occipital lobe; *pe*, "convolution of parietal eminence"; PO, occipital fissure; *pp*, "postero-parietal convolution"; R, central fissure; *sf*, superfrontal gyre; I, II, mesal transverse gyres, nearly at the level of the adjoining hemicerebrum; III, sloping cortical surface; IV, mesal gyres at a lower level than I and II.

Preparation.—The brain was taken from an epileptic imbecile, male, forty-eight years of age, 146.7 cm. (four feet ten inches) high, and weighing 55.7 kgm. (123 pounds). The entire brain weighed 1,111.7 gm. (39.25 ounces), of which the cerebrum constituted 978 gm. (34.5 ounces). Most unfortunately this rare, if not actually unique, specimen was simply placed in alcohol, which was not changed; hence the base was ill-preserved, and the ental features, although described in some detail by Turner, cannot be fully understood. A transection disclosed a single mesal, cerebral cavity, about 5 cm. wide, the floor of which is said to have been "formed of the upper surfaces of the corpora striata and optic thalami, which bodies were related to each other and to the *tænia semicircularis* as in a normal brain": yet "the third ventricle opened freely into the cerebral cavity along the middle of the floor." It is to be hoped that figures and more detailed descriptions may be published respecting the structure of this remarkable specimen. A good abstract of the original paper is given in *Brain*, i., 133-134, April, 1878.

§ 163. "*Third Ventricle.*"—The cavity commonly so-called really represents the mesal portions of the cavities of three segments; so much as lies between the thalami is the diacele; but the portion cephalad as far as the terma and fornix, although relatively small, pertains to the prosencephal and rhinencephal; in some lower vertebrates (*e.g.*, *Chimaera*, my paper, 1877, *a*) it is much more extensive.

§ 164. *Fig. 715 illustrates:* A. The fundamental morphological relation of each hemicerebrum as a lateral outgrowth, process, diverticulum, or "wing" of the mesal portion of the prosencephal.

B. The non-formation or obliteration of all the fissural corrugations and inequalities, excepting the Sylvian, which is a mere shallow depression extending obliquely dorso-caudad along the lateral aspect of each hemicerebrum.

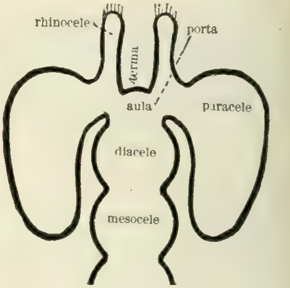

FIG. 714.—Diagram of the Prosocele and Adjoining Cavities.

C. The enormous size of the porta, yet the maintenance of its complete circumscription.

D. The tenuity of most of the parietes; in the occipital region they are no thicker than a sheet of ordinary paper, and are really exaggerated by the two ink lines and intervening space.

E. The extraordinary distinctness of the mass named *caudatum*, of which another view is given in Fig. 722.

F. The peculiar form and relations of the rounded mass intervening between the caudatum and the lateral wall, and which may represent the lenticula.

G. The non-appearance of the thalamus in the floor of the paracele.

H. Upon the whole, the retention, substantially, of a condition of the cerebrum comparable with the normal state at a much earlier period of development; it is, as it were, an expansion of such a cerebrum as exists at twelve weeks (see Fig. 667).

§ 165. *Paraceles* ("lateral ventricles").—But the lateral extensions speedily become so considerable as to warrant the specification of a mesal portion, *aula*, a pair of *paraceles* ("lateral ventricles"), and constricted communications, the *portas* ("foramina of Monro") (see Figs. 678, 684, 690, 723).*

§ 166. *Cornua.*—Each paracele is primarily subspherical and simple as in Figs. 667 and 678; in hydrocephalus this condition may be maintained approximately till birth (Fig. 715). But normally, by the unequal thickening of the parietes, by their encroachment upon the cavity, and perhaps by the further extension of the latter, there are somewhat vaguely demarcated a central *cella*, continuous through the *porta* with the *aula*, and three "horns," a ventral *medicornu*, a cephalic *precornu*, and a caudal *postcornu*. The last exists only in Primates (man, apes, monkeys, and lemurs) and a few other mammals, mostly members of the seal family. The cornua appear in Figs. 684, 720, 726, 735, and 736.

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* On this account it is to be the more regretted that so few such specimens are adequately preserved, examined, figured, described, and explained; indeed, no case is known to me in which the best possible use has been made of the opportunity; it is particularly desirable that, when malformation is suspected, the brain be thoroughly hardened by alinjection (injection of alcohol) of both the arteries and the cavities.

* If the rhinencephal is regarded as a segment, the aula and portas must be regarded as pertaining in part to it.

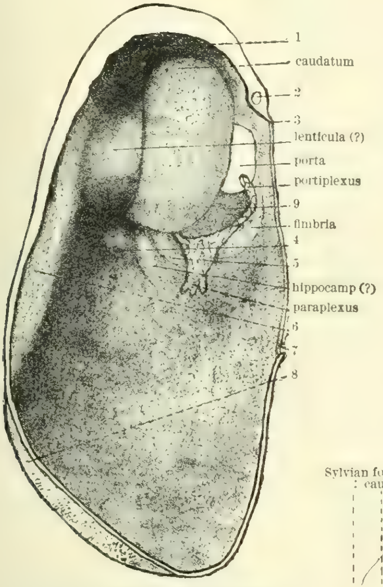

FIG. 715.—The Left Paracele (Lateral Ventricle) of a Female New-Born, (7 Months?) Hydrocephalus. No. 2,131. × 1. 1, One of several slight undulations of the ental surface in the frontal region; 2, slight pit, probably artificial; 3, cephalic margin of a break, apparently natural, in the mesal parietes; the ventral margin of this break is indicated by 7, and the corresponding caudal margin projects slightly mesad just caudad of the line; it may be supposed that this interruption of the mesal wall represents the location of the callosum that might have been formed; 4, 5, slight elevations as yet undetermined; 6, distinct though rounded ridge corresponding to the shallow Sylvian fissure, the only recognizable fissure; 7 (see 3); 8, occipital end of the hemicerebrum, projecting slightly beyond the cut surface; 9, membranous portion of the parietes (perhaps an attenuated tenia) through which the thalamus shows.

Preparation.—The child was supposed by the physician and parents to be seven months advanced; it breathed a few times; the weight was 1,618 gm. The neck and scalp were swollen, but the head was not unusually large. Normal salt solution was injected into the umbilical vein and escaped, with blood, from the jugular. Then half a litre of ninety-per-cent. alcohol was injected, the jugular being closed. The scalp, calva, and dura were removed, and the head supported in brine while the brain was extracted; in spite of care there was some separation of the hemicerebrums at the meson. The contained liquid was allowed to escape, the brain placed in ninety-per-cent. alcohol, and the hemicerebrums inflated to their natural size; they were then covered with a thin layer of absorbent cotton to keep them submerged. The alcohol was changed twice at intervals of two days, and on the fifth the various sections were made under alcohol. The mass supposed to represent the caudatum was extremely dense. The pia was firm, and in parts more substantial than the attenuated parietes. The condition of the diencephal was not fully determinable; the mesocele seemed to be wholly occluded, which would account for the condition of the cerebrum. The entire specimen needs further study and comparison with similar cases.

§ 167. *Fig. 716 illustrates:* A. The great extent of the paraceles at this period, relatively to the entire cerebrum, and to the mesal part of the prosocele, the aula.

B. The less difference in the thickness of the parietes than in the adult.

C. The distinct collocation of the hippocamp with the hippocampal fissure.

D. The topographical relation of the Sylvian fossa, the first stage of the Sylvian fissure, to the caudatum.

E. The extension of the postcornu farther caudad of the aula than the precornu extends cephalad.

F. The absence of the insula at this period.

G. The outgrowing margin of the operculum.

H. The depth and peculiar shape of the lambdoidal fissure (see Fig. 750).

§ 168. The *porta*, in a little modified condition, may be seen in the large salamander, *Cryptobranchus.* When the lateral wall of the alinjected hemicerebrum is removed (Fig. 717), the paracele is seen to communicate with a mesal space (aula) and thereby with its opposite and with the diacele, through a considerable orifice, the porta. Its caudal end is narrower than the cephalic, but it is seen to be completely circumscribed by ordinary nervous walls.

§ 169. *Fig. 717 illustrates:* A. The simple condition of the prosencephal in this amphibian; each hemicerebrum is an elliptical, thin-walled sac, the cavity of which, the paracele, communicates through a porta with the aula and so with the diacele.

B. The large size of the porta, its length equalling

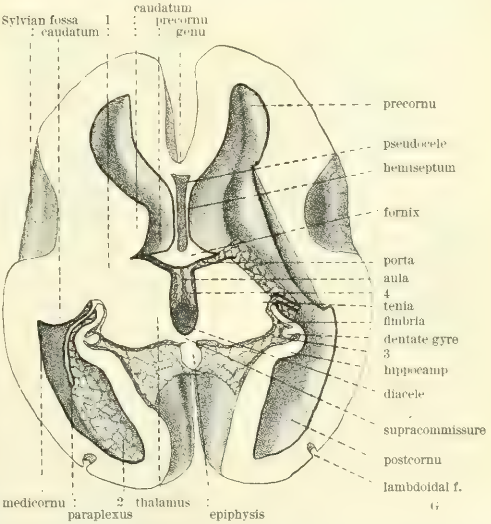

FIG. 716.—Ventral Exposure of the Prosocele of a Fetus about 24 cm. Long, and Estimated to be Twenty Weeks Old; 499. × 1.5. 1, Line of continuity of the thalamus and the caudatum; 2, thin extension of the paraplexus into the postcornu; soon after the preparation was made this became detached and was lost; another specimen must be depended upon to show whether or not such extension exists, and in what way it is disposed of in case it be deciduous; 3, hippocampal fissure; 4, diaplexus.

Preparation.—The brain was hardened in place by arterial alinjection; the scalp and calva were removed piecemeal, and the dorsal part of the cerebrum removed by one sweep of the knife under alcohol. The paraplexus was cut at each side as indicated by the heavy line (endyma) enclosing the lighter area. The left caudatum was removed so as to expose the paracele more completely on that side and make the figure comparable with that of the cat (Fig. 686).

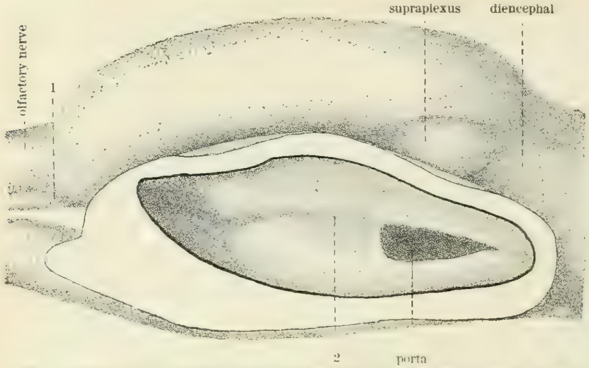

FIG. 717.—Prosencephal of *Cryptobranchus* (a Salamander), the Left Paracele Exposed; 291. × 6.
Preparation.—The fresh brain, while supported by the skull, was alinjected by lifting the metatela (membranous roof of the "fourth ventricle") and pointing the cannula at the broad epicele; the entire brain at once swelled somewhat, and the thinness of the walls caused it to harden almost immediately; the lateral wall of the left hemicerebrum was then sliced off, and the paraplexus cut off where it projected from the aula through the porta into the paracele.

about one-third that of the entire cerebrum; its cephalocaudal direction as compared with that of mammals, birds, and reptiles, where—especially in mammals—it is dorso-ventral.

C. The absence of a rima; the prosoplexus enters the aula from the supraplexus and sends a prolongation through either porta into the paracele, where it hangs freely.

§ 170. The porta is completely circumscribed, so that a cast has a definite outline, viz., that of an elongated ellipse, its longer diameter, 4–6 mm., its shorter 1–3 (see Figs. 718, 724). The portal boundaries are as follows: caudal, the thalamus (perhaps the tenia); cephalic, the column of the fornix; ventral, the junction of the thalamus and column; dorsal, the endyma reflected from the thalamus and column upon the intruded portiplexus (Fig. 668). So long as this endyma retains its adhesions, so long the circumscription of the porta is complete.

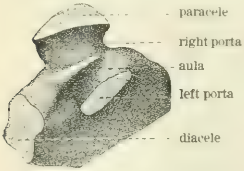

FIG. 718.—Cast of Aula, Portas, and Part of Diacele. × 1.5. The main object of the figure is to demonstrate the complete circumscription of the porta, and its independence of the rima (§ 177). The material used was a mixture of wax and gutta percha. The mesal ridge which represents the aulic recess is just dorsad of the precommissure (Fig. 724). The figure should have been so placed as to make this ridge nearly vertical.

§ 171. The exact conditions and relations of the rima, paraplexus, tenia, fimbria, and thalamus near the porta have not been as yet clearly made out. Preparations should be made with special reference to their elucidation, and figures upon a very large scale. Excepting the metapore ("foramen of Magendie") no part of the brain involves so many and so important morphological questions; see the difficulties and doubts admitted under Fig. 719.

§ 172. *Fig. 719 illustrates:* A. The size, form, and direction of the porta from the mesal aspect.

B. The complete circumscription of the porta, dorsad, by the reflection of the endyma upon the intruded plexus (Fig. 668).

C. The greater length of that part of the prosoplexus which hangs in the porta (portiplexus) than of that which hangs in the aula (auliplexus).

D. The constitution of the velum as a fold of pia, with blood-vessels intervening; one lamina of the fold belongs to the fornix, and the other to the thalamus, or rather to the diatela or primitive diacelian roof (Fig. 710).

E. The relation of the ventral end of the porta to the aulix ("sulcus of Monro").

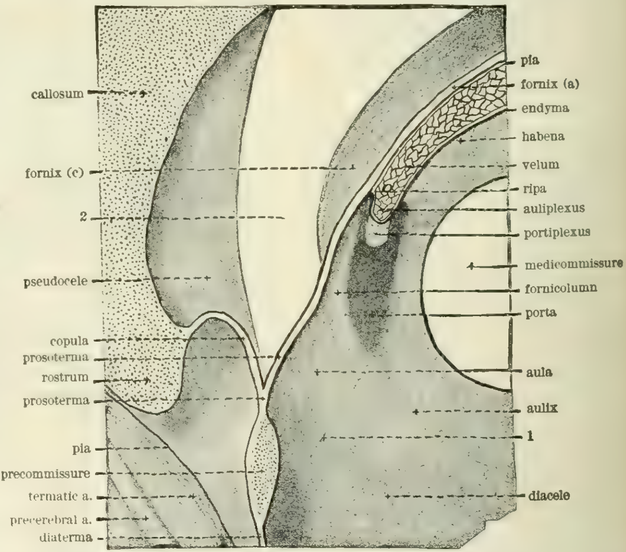

FIG. 719.—The Right Porta and Adjacent Parts, Seen Obliquely from the Caudal Side; 385. × 4. The lateral aspect of the left porta of the same brain is shown in Fig. 720, under which the mode of preparation is described. 1, Dotted line from the ventral end of the porta to the ventral margin of the precommissure, and assumed to demarcate the diacele from the aula; 2, part of the mesal surface of the hemiseptum, unusual and not fully understood (see § 172, H).

Defects.—The area marked 2 is not a cut surface as its plainness would indicate; it was shaded lightly in the drawing, but became blank in the engraving. The extent of the pseudocele and the length of the copula are so unusual as to be anomalous; these peculiarities, however, do not materially affect the porta, which is the important feature of the figure.

F. The thinness of the commissure of the fornix, *a*.

G. The unusual length of the copula connecting the callosal rostrum with the prosoterma.

H. The unusual extension of the pseudocele and of its lateral parietes, the hemiseptums; it is uncertain how far this existed naturally, or was produced by the pressure of alinjection.

§ 173. *Fig. 720 illustrates:* A. The location and general form of the paracele; unfortunately, however, the post-cornu is unusually short, and foreshortened by the way in which the preparation is viewed; but the sharp curve of the medicornu is well seen, and the projection of the precornu cephalad from the porta.

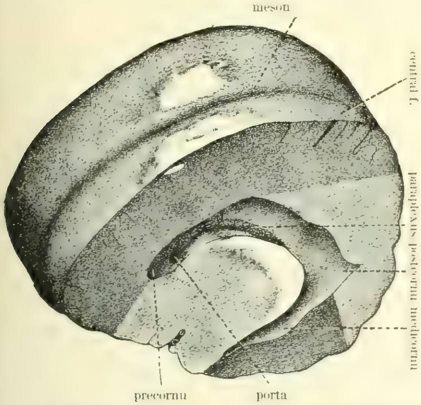

FIG. 720. The Left Paracele ("Lateral Ventricle"), Viewed Obliquely from the Latero-Cephalic Aspect; 385. × about .5. (This figure was published in the New York *Med. Jour.* for March 21, 1895, and is here reproduced by permission.)

Preparation.—The arteries and cavities were alinjected. When the brain was thoroughly hardened the medicornu was first exposed by removing successive slices of the temporal lobe till it was reached; contiguous parts were then removed till the entire paracele was brought to view; this involved the formation of five cut surfaces, all oblique excepting the most dorsal, which was about 1.5 cm. from the meson. The dura was retained until the preparation was complete and the drawing made; it has since been medisected, so that the left porta may be looked through.

B. The absence of any indication of a rhinocele, which exists in the sheep (Fig. 792), and in mammals generally.

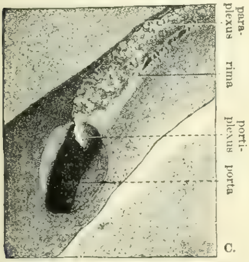

FIG. 721.—The Left Porta and Adjoining Parts of the Alinjected Brain Shown in Fig. 720; 385. × 3. The form of the lateral or paracelian orifice of the porta appears more distinctly, and the endyma is seen clearly to be reflected upon the portiplexus from the adjoining surfaces. Just dorsad of the line from *rima* are a few (presumably) artificial rents in the endyma.

C. The indistinctness of the colliculi, calcar, collateral eminence, and occipital eminence; whether this was due to hydrocephalus or to the pressure of the injected alcohol it is impossible to say.

D. The location and size of the porta, which is shown on a larger scale in Fig. 721.

E. The location of the paraplexus and of the rima through which it enters, covered, however, by the endyma (Fig. 759).

§ 174. *Fig. 722 illustrates:* A. The great size of the porta in this hydrencephal; its ventral half is concealed by the caudatum, but the total length (dorso-ventral dimension) is 19 mm. (three-fourths of an inch) and its width 8–9 mm.

B. The complete circumscription of the porta, notwithstanding the delicacy of the parts and the pressure that may have caused its enlargement.

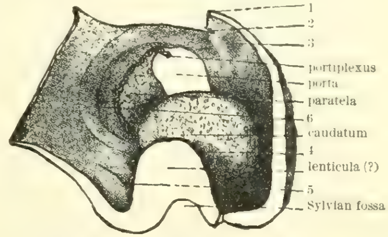

FIG. 722.—Lateral Aspect of the Right Caudatum and Porta (Foramen of Monro) of a New-Born (seven months ?) Hydrocephalus. 2131. × 1. 1, Angle between two cut edges of the thin mesal wall; 2, cephalic end of the natural (although presumably abnormal) hiatus in the mesal wall, corresponding with 3 in Fig. 715; 3, ental surface of mesal wall; 4, depression between caudatum and adjoining parietes; 5, triangular depression near tip of medicornu; 6, membranous part of parietes; see § 3, C.

Preparation.—See Fig. 715; the paraplexus on this side was trimmed closely.

C. The great extension of the paraplexus and adjoining portions of the parietes; the parts marked 6 and 7 are membranous; the zone just caudad of 7, and forming part of the upper margin of the figure, may be the fimbria; and the thicker zone just caudad of it may be the hippocamp.

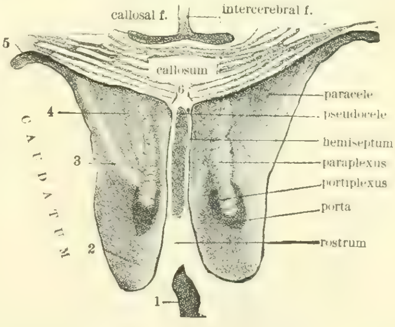

FIG. 723.—The Two Portas, from the Precornua; 2,345. × 1.5. 1, Part of the intercerebral fissure, between the rostrum dorsad and the chiasma ventrad; 2, precornu; 3, tenial vein; 4, undetermined band on the cephalic slope of the thalamus; 5, dorsal part of right paracele; 6, the short diverging lines point to the locations of veins (septal ?) at the angle of junction of the hemiseptums with the callosum; dorsad of the junction of the hemiseptums with the rostrum is a small (septal ?) vein at either side.

Preparation.—See under Fig. 724. The slice including the portas is 12 mm. thick; the caudal (aulic) aspect is shown in Fig. 724, the cephalic (precornual) in this.

Defects.—The shading does not indicate with sufficient distinctness that the entire surface, and plexus at either side dorsad of the porta, slope dorso-caudad beneath the callosum, and are not continuous with it. As in Figs. 724 and 739, the lines representing the callosal fibres are diagrammatic. Other preparations and figures upon a still larger scale are needed, in order to exhibit the somewhat intricate relations of the parts about the porta. The morphological importance of the entire aulic region can hardly be overestimated.

§ 175. *Fig. 723 illustrates:* A. The existence of the two portas, and their obviously natural condition. This point, already shown in several previous figures, is here reiterated because this aspect of these orifices is seldom presented, and because a distinguished anatomist has declared (*Progrès Médical*, Nos. 25 and 26, 1879) that when one finds a communication between the middle and lateral ventricles in an adult human brain it results from an artificial perforation; see my papers, 1884, *a* and 1884, *f*.

B. The transection of the callosum in two places, viz., dorsad near the genu and ventrad through the rostrum; the part of the septum or pseudocele here shown was therefore embraced by the genual curve of the callosum (see Figs. 687 and 756).

C. The continuity of the hemiseptum with the corresponding column of the fornix; so far as the porta is concerned, the former may be compared to a thin partition, and the latter to a door-post; see also Figs. 707 and 709.

§ 176. *Fig. 724 illustrates:* A. The existence, form, size, and complete circumscription of the two portas ("foramina of Monro").

B. The extent of the aula, the mesal division of the prosocele, and the cephalic or prosocelian constituent of the "third ventricle." It includes the interval between the portas, extending ventrad so as to include the precommissure, only part of which appears in the figure.

C. The existence of the aulic recess, a subtriangular depression between the precommissure and the two columns of the fornix; the line from the word *aula* ends in this recess; on the cast shown in Fig. 718, it is a ridge.

D. The peculiar curvature of the columns of the fornix. They converge dorsad, curving at the same time caudad, so as to appear as cut ends in this transection; ventrad they diverge, are twisted somewhat, and again curve caudad, so that their cut ends should appear again just dorsad of the optic tracts, as shown in Fig. 739.

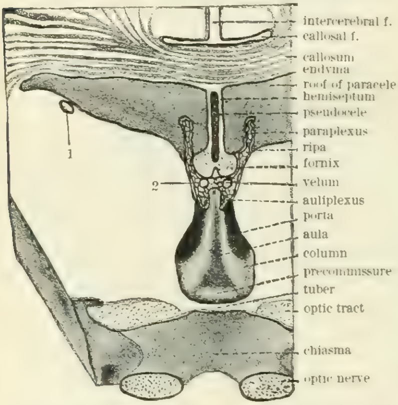

FIG. 724.—The Two Portas, as Seen from the Aula, Looking Obliquely Dorso-Cephalad; 2345. × 1.5. (Compare with Figs. 723 and 739.) 1, Temal vein; 2, velar vein; the number rests upon the thalamus.

Preparation.—From a brain, the arteries of which had been injected with the red glue mixture, and the cavities with alcohol, a transection was removed, 12 mm. thick, so as to include the chiasma; for security of handling it was trimmed down so as to include little more than the parts represented. The optic nerves were divided obliquely, to show their cut ends more fully.

Defects.—The alba and cinerea are not distinguished, and the figure is not upon a scale large enough to show certain details as to the connections of the velum and plexuses. The divided ventral ends of the columns of the fornix were inadvertently omitted, but may be seen in Fig. 739.

E. The relation of the precommissure to the columns, which pass just caudad of it. In a figure including a greater width of this region, the cut ends of the precommissure would appear at the side, as in Fig. 739.

F. The reflection of the endyma upon the plexuses from the fornix and thalami, at two points upon each side; such lines of reflection constitute a ripa.

G. The continuity of the hemiseptums with the callosum dorsad and the fornix ventrad.

§ 177. *Rima.*—The porta is primary, and constant among all vertebrates where the prosocele presents a tripartite condition (§ 60). In reptiles, birds, and mammals (perhaps also among some lower forms) at the dorsal end of the porta there begins a line of greater or less length along which the proper nervous parietes of the paracele are abrogated for the intrusion of a pial extension, the paraplexus; this line of intrusion is the rima (chief part of the so-called "great transverse fissure") shown in Figs. 720, 725 (diagram), 730, and 735. It is to be noted that (1) the paraplexus fills the space, and (2) the endyma is carried before it, so that there is no true solution of continuity. The only way in which the porta and the rima can become continuous is by the artificial rupture of the membranous attachment, but this is by no means infrequent with brains removed and handled in the usual way.

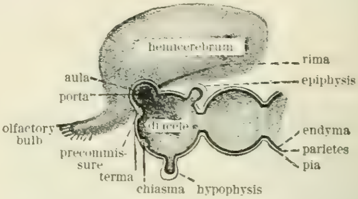

FIG. 725.—Schematic Medisection of the Prosencephal and Two Adjoining Segments; approximately the right half of Fig. 714, seen from the mesal aspect. (See § 178.)

§ 178. *Fig. 725 illustrates:* A. The communication of the paracele (lateral ventricle) with the mesal series of encephalic cavities solely through the porta ("foramen of Monro").

B. The reduction in size of the aula, the mesal division of the prosocele, relatively to the diacele, and to the prosocelian lateral extensions, the paraceles.

C. The location, in man and other mammals, of the aula at the dorso-cephalic side of the diacele, instead of directly cephalad as in Amphibia.

D. The concomitant change in the direction of the diacelian and prosocelian floors; instead of cephalo-caudal, their direction is more or less nearly dorso-ventral.

E. The crowding of the epiphysis caudad by the overlying cerebrum; the epiphysis and hypophysis are retained in the figure, however, mainly as landmarks.

F. The relation of the rima (essential part of the "great transverse fissure") to the porta. The line along the meso-ventral aspect of the hemicerebrum represents a narrow tract where the paracelian parietes are reduced to the lining endyma and the covering pia, and where the latter, or its vessels, intrudes into the paracele, still covered, however, by the endyma. The rima always begins at the margin of the porta, and extends, in man, to near the tip of the medicornu (see § 183 and Figs. 728 and 734).

G. The secondary and morphologically unessential nature of the caudato-thalamic extension, the enormous thickening of the thalamus, the lateral wall of the diacele, and of the caudatum, the wall and floor of the paracele. This feature of the mammalian brain, which is very confusing and not altogether easy to describe, may be ignored in a diagram like the above, where the parietes are represented of nearly uniform thickness, as in the embryo and in adult amphibians.

§ 179. *Fig. 726 illustrates:* A. The close contact and even interdigitation of the mesal aspects of the frontal lobes of the sheep concomitantly with the absence of a falx.

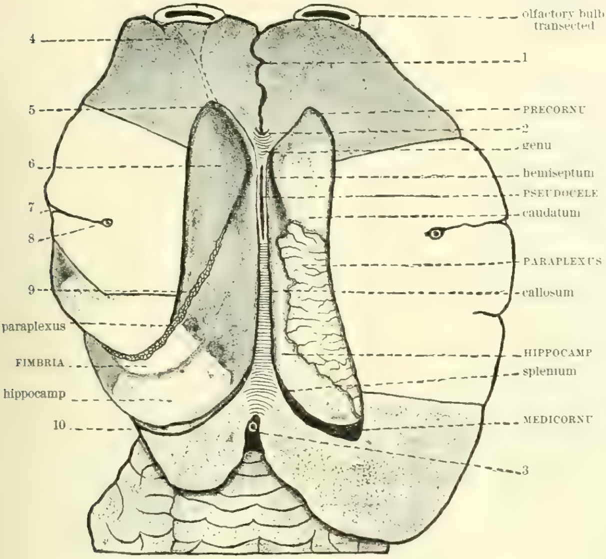

FIG. 726.—Sheep's Brain, the Paraceles ("Lateral Ventricles") Exposed. × 2. (From my "Physiology Practicums.")

Preparation.—By the removal of successive slices the paraceles have been opened; the left has then been more completely exposed by oblique sections, and the paraplexus trimmed off so as to expose the wide fimbria and the furrow between it and the hippocamp. The plane of section did not coincide exactly with the callosum; the caudal three-fifths of this is represented by the transverse lines; also the cephalic end, the genu; but an intermediate portion is wholly removed, exposing the narrow pseudocele ("fifth ventricle") and its thin lateral walls, hemiseptums.

Defects.—The cerebral cortex is not represented. The caudal half of the cerebellum is omitted.

1, Intercerebral fissure; 2, callosal fissure; 3, vessel; 4, interrupted lines indicating the continuation of the paracele into the rhinocele (Fig. 792); 5, precornu; 6, caput of the caudatum; 7, Sylvian fissure crossed by arachnoid; 8, vessel at bottom of fissure; 9, cauda of caudatum; 10, part of caudal wall of paracele.

B. The width of the fimbria and hippocamp, and thence of the entire fornix, as compared with the human.

C. The apparent absence of the tenia.

D. The total exclusion of the thalamus, even in appearance, from the paracelian floor.

§ 180. *Fig. 727 illustrates:* A. That, at this age, the paraceles extend much farther dorsad than in the adult, far beyond the level of the callosum.

B. That the paraplexus is relatively more extensive.

C. That the caudatum is relatively larger.

D. That the margin of the fimbria reaches the groove between the caudatum and the thalamus, which probably represents the tenial sulcus of the adult.

E. That the thalamus is therefore absolutely excluded from the paracelian floor, without even the appearance of representation which exists in the adult.

§ 181. With all mammals other than man, the apes and certain members of the seal family, the margins of the rima are, throughout their whole extent, separated only so far as to permit the intrusion of the paraplexus, *e.g.*, the sheep (Fig. 726); nor does this adhesion yield at all in cases of hydrocephalus, observed by me in dogs and cats. With the human fetus, also, up to the estimated age of four months (Figs. 727 and 734), at least, the tenia and the fimbria are closely apposed—as closely, that is, as they can be and yet allow the plexal intrusion; at this age, therefore, the human thalamus is as perfectly excluded from the paracele as it is in mammals generally.

§ 182. *Paratela.*—But with all human adults (perhaps also with the new-born, and possibly with fetuses during the later months) the tenia and fimbria, for most of their length, are separated by an interval, 2–7 mm. in width, narrowing at the porta and in the medicornu. This interval is filled by (1) the paraplexus, which retains its attachment to the fimbria rather than to the tenia; (2) an extension of the endyma from the margin of the tenia with or without the adhesion of the subjacent pia. This zone of endyma, or endyma and pia, extending from the porta to near the end of the rima is the *paratela* (Figs. 732, 735).

§ 183. *Fig. 728 illustrates:* A. The existence of substantial walls of nervous substance about the medicornu at the distance of at least 1 cm. from the tip of the temporal lobe.

B. The concomitant non-extension of the rima ("great transverse fissure") to the extremity of the medicornu.

C. The existence of digitations at the ventral end of the hippocamp (*pes hippocampi*).

D. The non-extension of the hippocamp to the extremity of the medicornu.

E. The dilatation of the medicornu in hydrocephalus.

F. The efficacy of alinjection in maintaining the size of an encephalic cavity and preserving the contour of its parietes.

G. The nearly typical zygal, or H-shape, of the orbital fissure (see Fig. 778, III.).

§ 184. *The Rima Not Coextensive with the Medicornu.*—The rima extends from the porta to near the extremity of the medicornu, but for about 1 cm. from its extremity

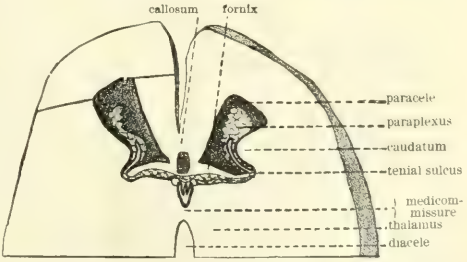

FIG. 727.—Transection of the Brain of a Fetus, About 16 cm. from Nates to Bregma, and Estimated at Four Months; 1816. × 1.3.

Preparation.—The fetus was received in alcohol, not very well preserved. The calva was cut away with scissors, and the dura and pia removed. The entire brain was then transected at the level of the medicommissure, but only the dorsal half of the divided surface is included in the figure; it is the cephalic aspect of the caudal part. The two lines crossing the right hemicerebrum indicate the plane of the section shown in Fig. 761.

the parietes are substantial (Fig. 728). The transition to the rima is constituted by the riparian part, *pala*, which connects the two rimal margins, fimbria and tenia. This thin portion has, in man, a shape like the blade of a turf-cutter; it is not distinctly shown in any of the figures in this article, but in Fig. 730 it would constitute the thin lamella at the ventral end of the fimbria. In the diagram, Fig. 729, the pala is seen in transection at B.

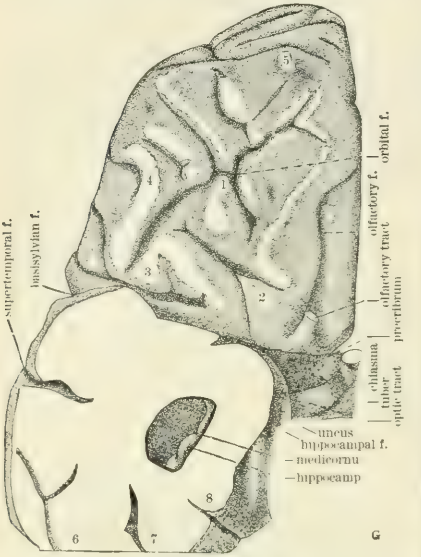

FIG. 728.—Ventral (Orbital) Aspect of the Right Fronto-Temporal Region of the Hydrencephal Shown in Fig. 743, after removal of the tip of the temporal lobe; 747. × 1. 1, Zygon of the orbital fissure (see Fig. 778); 2, 3, 4, undetermined fissures; 5, undetermined fissure, zygal in form, perhaps the orbito-frontal; 6, meditemporal (?) fissure; 7, subtemporal (?) fissure; 8, collateral fissure.
Preparation. See Fig. 743.

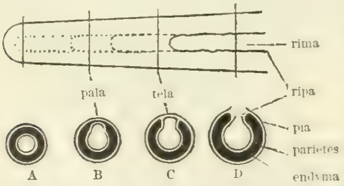

FIG. 729.—Schematic Transections of the Medicornu at Four Different Levels. For simplicity the cornu is represented as tubular and straight, normalized, so to speak (§ 38), and the parietes merely as substantial tissue covered by pia and lined by endyma. For some distance from its extremity (1-2 cm. in man) the medicornual parietes are typical, as at A; this condition of the parts appears in Fig. 728. The proper nervous parietes suddenly become very thin and transparent, so as to resemble the terma and valvula, as at B. At C the proper nervous parietes have entirely disappeared, leaving only the two membranes; this is the normal constitution of a tela, and sometimes exists near the tip of the medicornu, though relatively for a much less distance than on the diagram. Finally, whether or not a plexus is intruded into the cavity, as is the case with the medicornu, the tearing away of the tela leaves a ragged edge which is a ripa at either side of the rima.

§ 185. *Fig. 730 illustrates:* A. The early and distinct formation of the caudatum (see also Fig. 715).

B. The continuity of the two margins of the rima, the fimbria and tenia, near the tip of the temporal lobe, the place of their union, at and after birth, being somewhat distinct, the pala.

§ 186. *Fig. 731 illustrates:* A. The thinness of the fornix at the meson (§ 202).

B. The considerable extent of the pseudocele; since this is not connected with the true encephalic cavities, it cannot be exaggerated by the hydrocephalous condition.

C. The completeness of the paracelian floor after the removal of the thalamus; the interval, rima, between the substantial tenia and the lateral margin of the fornix (fimbria) is completely filled by the paraplexus and the paratela.

D. The greater width of the rima in the cella than near the end of the medicornu.

E. The extension of the calcarine fissure (stem of united occipital and calcarine) across the hippocampal gyre; it does not, however, reach the hippocampal fissure.

§ 187. *Fig. 732 illustrates:* A. The main point is the continuity of the floor of the paracele ("lateral ventricle") irrespective of the dorsal surface of the thalamus, and the concomitant exclusion of this diencephalic mass from this portion of the prosencephalic cavity; but so many other points are shown incidentally that the figure will be described in detail.

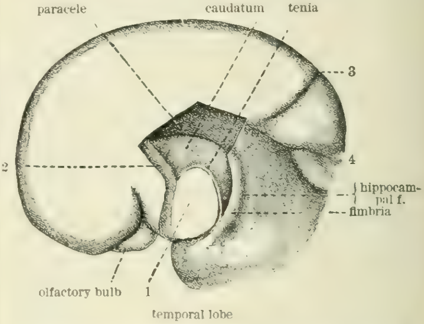

FIG. 730.—Mesal Aspect of a Right Fetal Hemicerebrum, Partly Dissected; 3,000. × 2.5. 1, Transection surface between the caudatum and thalamus; 2, part of cut surface left by removing a section of the mesal wall (including the rudimentary fornix and callosum) in order to expose the caudatum; the paraplexus was also torn from its attachments, leaving the rima open; its margins, the tenia and fimbria, are separated more than is natural; in a fetus of this age they should be closely apposed (see § 181 and Fig. 727); 3, 4, transitory fissures in the places of the future occipital and calcarine.

Beginning at the dorsal side of the figure, the intercerebral fissure is seen to separate the apposed mesal surfaces of the hemicerebrums. The arachnoid dips into this fissure to a certain depth, so as to pass around the ventral margin of the falx (not shown in the figure); since this has (as seen in Fig. 801) a curved margin, and becomes narrower (dorso-ventrally) cephalad, the extent of the arachnoidal fold varies at different levels; in the specimen here figured, for example, which is about 1 cm. thick at the level of the callosum, the arachnoid crosses 5 mm. dorsad of the callosum on the caudal aspect and 8 mm. on the cephalic. The pia, however, follows the apposed hemicerebral surfaces to and into the callosal fissure at either side and is continuous upon the dorsal surface of the callosum. Of the vessels the figure includes only the two parallel precerebral arteries (4). The callosum itself presents a slight mesal elevation, which is more distinct at the cephalic side of the section and of a somewhat different color (§ 217). The callosum extends laterad and likewise dorsad to form the roof of the paracele, and it is to be noted that the lateral portion of this cavity would be opened by a horizontal section at the level of the dorsal surface of the callosum; hence the appearance commonly described and figured under the name of "*centrum ovale majus*" seldom if ever exists. For the condition of things in fetal brains, see Fig. 727, § 180.

Ventrad of the callosum is the fornix, connected therewith by a thin lamina, the hemiseptum, at either side of a mesal cavity, the pseudocele. The lateral margin of the fornix is formed by the fimbria (corpus fimbriatum).

At the extreme left of the figure the lateral wall of the paracele is seen to be formed by a cinereal mass, the caudatum. By reference to Figs. 707 and 735, it will be seen that this narrows rapidly from the cephalic end (caput) as a slender prolongation (cauda); but this cauda is really folded somewhat upon its longitudinal axis so as to constitute, in at least part of its course, not only the side but a part of both the roof and floor of the paracele; in the figures just mentioned the roof portion and part of the lateral is removed, leaving only the floor portion. Along the mesal border of the cauda there passes a vein (3), the tenial vein, which may be regarded as indicating the boundary between the caudatum and the thalamus.

Projecting mesad of the vein is seen a lamina, consisting evidently of the paracelian endyma, and also, at least near the caudatum, of some nervous substance; this is, or includes, the white band named *tenia* in this article, but commonly called *tænia semicircularis* or *stria cornea*.

All the parts so far described are unquestionably constituents of the prosencephal; the remaining portions shown in Fig. 732 belong to the diencephal. The walls of the diacele are the thalami, of which the figure includes only the portions dorsad of the level of the medi- and postcommissures (see Fig. 687).

The mesal surface is covered by endyma, which is continued over the low ridge called habena ("habenula") seen from the mesal aspect in Fig. 687, and from the dorsal in Fig. 707. Just dorsad of the habena is a slight furrow, the habenal sulcus; here the endyma meets the pia covering the dorsal aspect of the thalamus, and is reflected with it dorsad and then mesad toward the opposite side. Instead of passing horizontally across the interval between the thalami, however, the endyma is deflected over the two vascular plexuses (folds of pia or vessels therefrom) which hang in the diacele. The habena and its sulcus, more accurately, perhaps, the latter, constitute the boundary line between the mesal, entocelian, endymal surface of the thalamus, and the dorsal, ectocelian, and pial surface, which extends dorso-laterad.

Between the dorsal surface of the thalamus and the ventral surface of the fornix (including, of course, the fimbria), the pia is freely separable, and appears to consist of but a single layer; but laterad it is traceable to the paraplexus, and it is almost inconceivable that a plexus should be formed of a single layer of pia as a free edge covered by endyma. When, however, this fornico-thalamic pia is traced mesad, it is found to separate into two layers, a dorsal, belonging to the fornix, a ventral, constituting part of the diacelian roof (diatela) with a pair of arteries, a pair of veins, and numerous smaller vessels in the intervening space. The ventral layer is not separable (in man) from the diacelian endyma, but the dorsal not only may be detached from the fornix in an alcoholic specimen, as may the pia from most of the surfaces which it covers, but here, excepting at the margins, the disjunction was almost spontaneous, and there is a distinct space (8) between it and the commissure, bounded at the sides by the thicker (hippocampal) constituents of the fornix. This double curtain of pia is the velum (interpositum), which belongs equally to the diencephal and to the superposed prosencephal. Were it possible in separating the two segments, the dorsal layer should accompany the cerebrum, and the ventral remain attached to the thalami; the continuity of the two is seen at the aula and the two portas, as well as along the entire margin of the paraplexus (see Figs. 710 and 737).

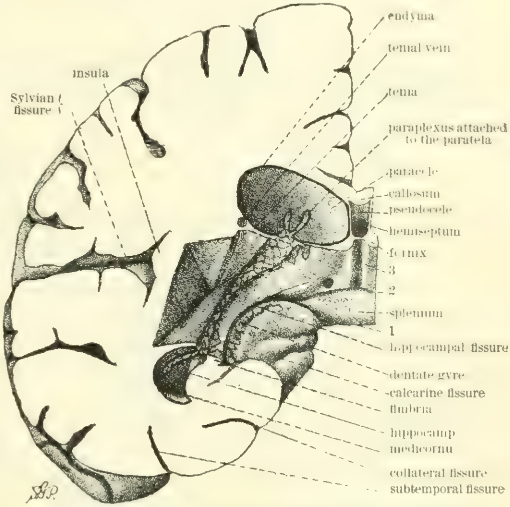

FIG. 731. Transection of the Right Hemicerebrum of an Adult Hydrocephalus; 747. × 1. 1, Ventral curvature of splenium; 2, groove at cephalic margin of splenium; 3, mesal furrow of fornix (the line does not quite reach it). The furrow between the lines from *hippocampal fissure* and *dentate gyre* is the continuation of the callosal fissure, separated from the hippocampal by a flattened area of cortex. The deep fissure opposite the word *insula* is the central.

Preparation. This represents the cephalic aspect of the caudal part of the hemicerebrum, the mesal aspect of which is shown in Fig. 743. The transection was along the oblique line *d-e* on that figure. So much of the thalamus as was included was cut away, together with some of the adjoining prosencephalic mass, capsula, lenticula, and perhaps claustrum, leaving little more than the cortex of the insula at that point.

Defects.—The shading does not discriminate sufficiently between the natural and artificial surfaces, but the former are curved while the latter are straight and bounded by sharp lines. The alba and cinerea are not distinguished. The left hemiseptum is added by dotted lines.

Corresponding with the margin of the fimbria, the dorsal surface of the thalamus presents a shallow groove, the fimbrial sulcus ("sulcus choroideus," Fig. 707); laterad from this the surface is nearly regular, and overlaid partly by the paraplexus and a membrane apparently endyma only, and partly by the thin but more substantial lamina (tenia?) already described as an extension of the caudatum.

The entire dorso-mesal surface of the thalamus, instead of being homogeneous, as it has been sometimes figured and described, may be divided, first and most sharply into a mesal, or entocelian, and a dorsal, or ectocelian, portion, the boundary between the two being the habena and its sulcus. The dorsal surface itself presents a twofold division into a subfornical (B) and a parafornical (C and D), separated by the fimbrial or choroid sulcus. Finally, the parafornical area is covered partly by the paratela and plexus and partly by the tenia, and may thus be distinguished as subparatelar (C) and subtenial (D), there being occasionally a furrow, the tenial sulcus, between them. The desirability of discriminating between these areas will appear in connection with Fig. 733, where certain different, and perhaps anomalous, conditions are described.

So far as this preparation is concerned, there is absolutely no adhesion of endyma to any part of the thalamus dorso-laterad of the habenal sulcus; on the contrary, the endyma is traceable in uninterrupted continuity about each paracele, over, in turn, the ventral surface of the callosum, the caudatum, the tenia, the paraplexus, the fimbria, the thicker portion of the fornix, and the hemiseptum, back again to the callosum.

§ 188. With some specimens the interval between the paraplexus and the caudatum seems to be occupied by a somewhat substantial lamina, separable from the thalamus, continuous with the caudatum, and perhaps merely a special development of the tenia, but requiring further investigation (Fig. 733).

§ 189. The point illustrated upon Fig. 733 is the continuity of the paracelian floor from hippocamp to caudatum without the intrusion of the thalamus. This figure is to be studied in connection with the transection (Fig. 732), and the dorsal view of the floor in Fig. 735.

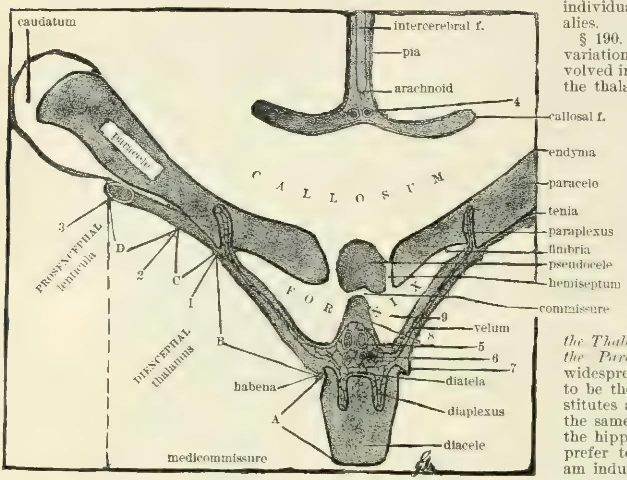

FIG. 732.—Transection, Partly Schematic, of the Fornix and Adjacent Parts at a Level Corresponding with the Interval between the Medicommissure and the Postcommissure; 1,824. × 2.5. 1, Fimbrial sulcus ("sulcus choroideus"); 2, tenial sulcus (in some specimens); 3, tenial vein; 4, precerebral arteries; 5, velar veins; 6, velar arteries; 7, habenal sulcus; 8, interval (natural ?) between the velum and the commissure of the fornix; 9, lateral part of the fornix (hemifornix); A, mesal, endymal surface of thalamus; B, C, D, zones of its dorsal surface; B, subfornical; C, subendymal; D, subtenial. Between the left paraplexus and the tenia the membranous floor of the paracele is the paratela.

The figure represents the caudal surface of the transection; the observer is looking cephalad, and his right coincides with the right of the specimen and the figure; the two sides are substantially identical, but less is shown upon the right; the meson of the figure, the anatomical middle of the various parts and cavities represented, is dextrad of the middle of the area covered by the figure. Throughout the figure the cavities are shaded and the blank areas represent transected surfaces. The arachnoid is represented by a narrow, straight line, the pia by a corrugated line, and the endyma by a heavy line; the endyma is made to adhere closely to the entocelian surfaces, but the pia and arachnoid are separated slightly from the parts which they cover.

Preparation.—See Fig. 744, representing another transection of the same brain. The celian parietes were thoroughly hardened before the brain was removed from the skull, and the membranes and plexuses have retained their connections notwithstanding much handling and considerable transportation. There is some distortion and dislocation of the loosely connected parts about the fornix, but it has been possible to clear up most of the doubtful points by comparison of the two sides and with adjoining sections. So far as respects the exclusion of the dorsal surface of the thalamus from the paracele, the preparation affords unequivocal evidence.

Defects.—As in several other figures representing transections of plexuses, it has been assumed that a plexus consists of a fold of pia covered by endyma; for present purposes it matters not whether there is a complete fold of the pia, or merely an extension of vascular loops. The ventral lamina of the velum is made too low. The medicommissure, the dorsal margin of which is included at the ventral side of the figure, did not actually appear in this section, which was just caudad of it, but is introduced as a readily recognized landmark. The indusium is not shown (§ 217).

There are, however, differences between these and other preparations which are not easy to explain, excepting upon the general supposition that a region in which the conditions are nearly peculiar to the human brain might naturally be expected to present individual peculiarities and even anomalies.

§ 190. There seems to be considerable variation in the details of the parts involved in the apparent representation of the thalamus within the paracele; this is perhaps to be expected, since the conditions that have made the usual statements possible constitute a great and perhaps peculiar modification of the primitive and typical relations—indeed, almost a malformation.

It is hoped that the foregoing descriptions and figures may at least serve to induce anatomists to investigate the subject in all its bearings.

§ 191. *In What Sense does the Thalamus Form Part of the Floor of the Paracele (Lateral Ventricle)?*—So widespread and so deeply rooted seems to be the notion that the thalamus constitutes a part of the paracelian floor in the same sense as do the caudatum and the hippocamp, that, much as I would prefer to avoid the critical attitude, I am induced to comment upon the current representations of this region.

Admitting, for the sake of occupying common ground, that a certain area of the dorsal surface of the human thalamus is covered by endyma; that it is continuous with the caudatum, and that therefore, like that body, it enters into the composition of the paracelian floor; none will deny that an adjoining area of this same dorsal surface is as distinctly covered by pia; that it is continuous with the optic lobes (gemina), and like them wholly excluded from the encephalic cavity.

To represent the entire dorsal aspect of the thalamus as a smooth, unbroken surface is practically to affirm one of two things: either the whole is pial or ectocelian, which would be in contravention of the obvious facts; or else the whole is endymal or entocelian, which would involve not only the gemina but the cerebellum and oblongata, a manifest *reductio ad absurdum.**

§ 192. *The Colliculi.*—This collective term is applied to the rounded eminences and ridges which project into the paraceles ("lateral ventricles") from their parietes. They are the caudatum (caput and cauda), hippocamp ("*hippocampus major*"), calcar ("*hippocampus minor*"), collateral eminence, and occipital eminence. Excepting perhaps the first, each of these represents a corrugation of the entire thickness of the parietes, the ental elevation (colliculus) being collocated with an ectal depression (fissure); this collocation is indicated in the list of total fissures, § 258.

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* For a fuller discussion of the relations of the thalamus to the paracele, and for commentaries on the misrepresentations in standard works, see the first edition of the REFERENCE HANDBOOK, viii., 144–147, and ix., 107, and my papers, 1888, *a*, and 1889, *d*. The delicacy of the membranes, the readiness with which they are detached along a ripa, the rough handling to which brains are commonly subjected during the ordinary processes of removal and examination, the slight degree in which preservatives can reach the parts in question when the entire organ is merely immersed as usual, and, finally, the fact that some agents, excellent for microscopic purposes, do not well preserve the endymal attachments—all these conditions conspire to bring it about that the endyma across the wide rima should be torn, and the dorsal surface of the thalamus protrude through the rent.

§ 193. *The Callosal Eminence.*—Besides the colliculi named in § 192, all of which are more or less distinct in at least some adult brains, there is one which is perfectly obvious in some fetuses (Fig. 734, 1), and which, from its apparent collocation with the callosal fissure (Fig. 742), may be called, provisionally, the callosal eminence. It, the hippocamp, and the occipital eminence form an irregular triradiation. Its commencement and disappearance require further observation, but its unbroken continuity with the hippocamp confirms the idea that the callosal and hippocampal fissures are essentially parts of one, merely deflected by the splenium of the adult.

§ 194. *The relative size* of the colliculi is not the same in the adult as in the fetus. This is clear from the comparison of Fig. 734 with Figs. 744 and 761. The callosal eminence may disappear wholly; the occipital is seldom recognized (Fig. 744); the collateral is certainly less prominent in the adult than in the fetus (Fig. 734).

§ 195. *Fig. 734 illustrates:* A. The contiguity of the margins of the fimbria and the tenia (the edge of the caudatum) with just room for the entrance of the paraplexus, and the concomitant complete exclusion of the thalamus from the paracelian floor (compare Figs. 732 and 733).

B. The existence of an ental ridge (1) at this period, continuous and corresponding with the hippocampal and callosal fissures; whether it extends still farther cephalad, as in Fig. 742, cannot be ascertained from this specimen.

C. The branching off of a ridge corresponding apparently to the occipital fissure, and representing the adult occipital eminence.

D. The existence of two intermediate ridges, perhaps prefiguring the calcar and collateral eminence.

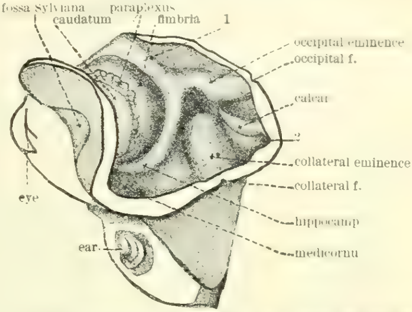

FIG. 734.—Left Hemicerebrum, Laid Open, of a Fetus Weighing 88 gm. (3 ounces), Measuring 15 cm. from Heel to Bregma, and Estimated at Fourteen Weeks; 2,083. × 1.5.

Preparation. The fetus was received fresh; the head was cut off and pinned by the neck to a cork loaded with sheet lead; a shawl pin was inserted as a handle at one side of the head. A slit was made through the scalp at the lateral angle of the prefontanel, and the guarded cannula adjusted so that ninety-five-per-cent. alcohol should enter the paracele gently, with opportunity for egress at the side of the cannula. After six hours the alinjection was discontinued, but the specimen remained in alcohol for two days, when the scalp was removed and the specimen placed in ten-per-cent. nitric acid. After five hours the calva was so far decalcified that it could be cut away with the scalpel and scissors without jarring the very delicate brain. The left hemicerebrum was then exposed as indicated, and the nape of the neck removed to expose the collateral fissure. Upon a larger scale some of the points would have appeared more clearly.

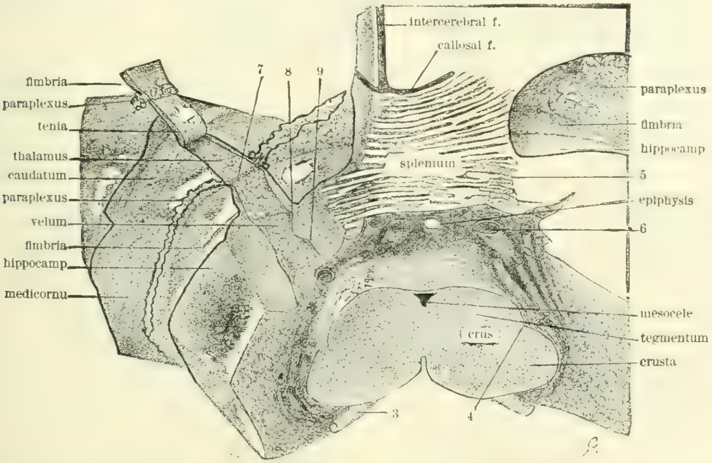

FIG. 733.—Dissection, Partly Schematic, of the Floor of the Left Paracele ("Lateral Ventricle"), Caudal Aspect; 2,345 and 2,347. × 1.5. Compare in part with Fig. 706. 4, Lateral sulcus of the mesencephal; 3, oculomotor nerve; 5, line of somewhat sudden deflection of the splenial fibres caudad into the occipital lobe; 6, large vein; 7, fimbrial sulcus; 8, angle between the fimbria and the hippocamp; 9, hippocampal fissure.

Preparation.—The arteries were injected with the red glue mixture, and the cavities with alcohol. When hardened, a thick slice was taken by one transection at about the middle of the length of the callosum and another at the splenium, just shaving off the tip of the epiphysis. The original transection of the brain stem between the mesencephal and epencephal was modified by carrying two sections cephalo-mesad, meeting at the level of the valvula. On the right of the cerebrum the parts were left undisturbed, excepting that the paraplexus was raised so as to expose the floor of the cavity. On the left, a thin slice of the hemicerebrum is left attached to its opposite by the pia. In order to expose the paracelian floor as completely as possible from this point of view, the sections had to be made in many directions. The paraplexus was trimmed down for a certain distance; then a wedge-shaped piece was cut from the thick caudal wall, hippocamp, etc., including part of the thinner floor, fimbria: this exposed the velum, the double fold of pia between the dorsal surface of the mes- and diencephal and the ventral surface of the fornix. Very cautiously then the two parallel incisions were carried across the floor to and into the caudatum constituting the lateral wall; the strip so enclosed was then lifted; it included (1) a piece of the fimbria; (2) the disconnected part of the paraplexus; (3) a strip of the thin lamina intervening between the plexus and the caudatum; in 2,347 all these were found separable from the dorsal surface of the thalamus, substantially as in the transection, Fig. 732; in 2,345 there were complications which should form the subject of monographic consideration. See § 189.

Defects.—The defects of the figure are due mainly to the attempt to combine the appearances presented by two different preparations.

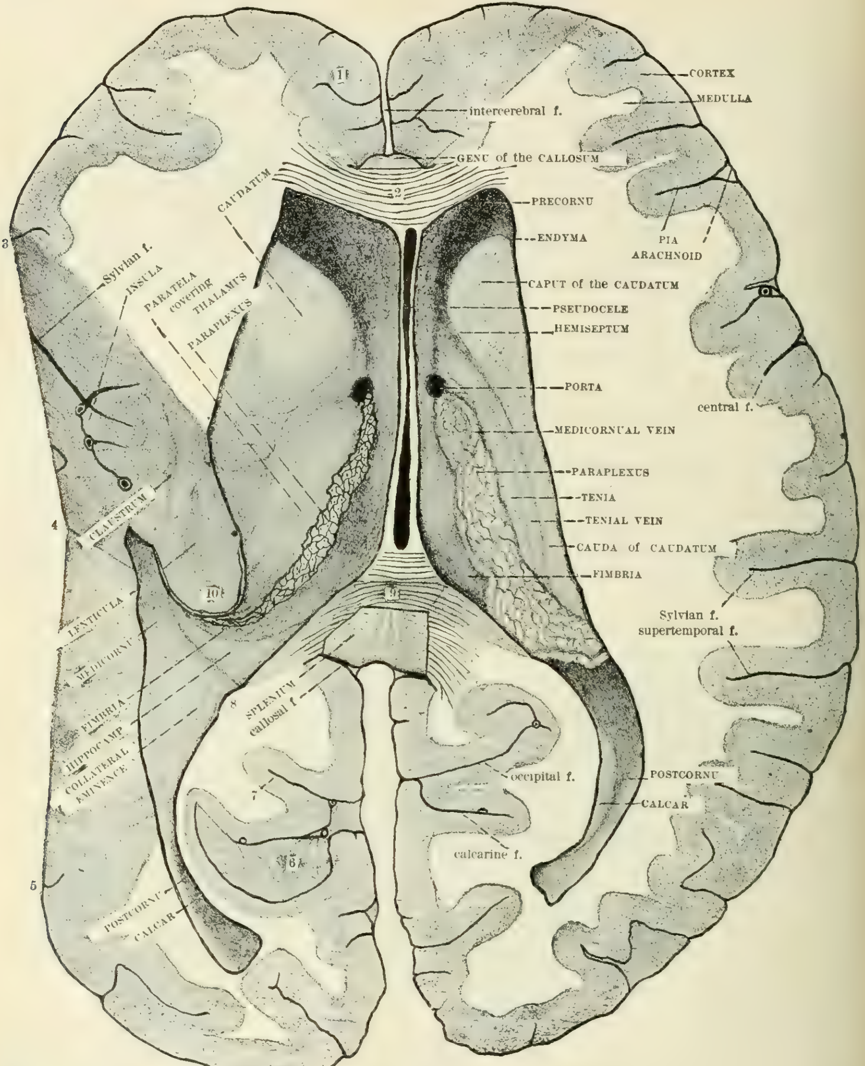

FIG. 735.—The Paraceles ("Lateral Ventricles") of an Adult Male, Exposed from the Dorsal Side; 2,867. × 1.2.

Preparation.—The entire body (an emaciated consumptive, weighing only 37.71 kgm., 83.25 pounds) was alinjected through the femoral artery. Eight and one-half litres were introduced on the first day, and some escaped from the mouth. On the second day, and again on the fourth, another litre was injected. On the fifth day there was injected a litre of Pansch-Gage starch mixture (see article ***Brain: Methods***, etc.). When the brain was removed, on the eighth day, the only odor was of the alcohol. The substance had already hardened somewhat and the arteries were well filled, notwithstanding some of the mass had extravasated into the thorax. The brain was transected through the mesencephal (see *Brain: Methods*), and the paraceles exposed by removing the dorsal portion of the cerebrum in thick slices down to the level of the callosum; then in thinner slices and wedge-shaped pieces till the desired condition was reached. On the left the medicornu was exposed into the part extending cephalad; the terminal portion extending also mesad could not be shown without cutting away an undesirably large mass. On the left also the occipital lobe was cut to a slightly lower level than on the right; hence, on the right appears the dorsal slope of the calcar, while on the left the plane of section coincides with the line of its greatest elevation, and the width of the postcornu is correspondingly reduced. To lessen the width of the figure a part of the lateral convexity was removed by dorso-ventral incisions between 3 and 4, and 4 and 5, so the line representing the pia ceases at 3 and 5. Finally, the left paraplexus was trimmed off quite closely. (For the rest of this explanation, see at bottom of page 179.)

§ 196. *Fig. 735 illustrates:* A. The general relation of the paraceles (lateral ventricles) to the cerebrum; although relatively much smaller than in the fetus, they are absolutely extensive; here their natural extent has been maintained by the injection of alcohol; when examined in a fresh brain or in one hardened in the usual way their walls are often found nearly in contact.*

B. The terminal dilatation and squareness of the postcornu, as contrasted with the pointed form which usually exists in brains not prepared by filling the cavities; sometimes, indeed, there has been doubt as to the extent of the postcornu, as admitted by Huxley, Zoöl. Soc. Proceedings, 1861, p. 250; in Krause's "Handbuch" (1880), Fig. 479, the postcornua are merely linear.

C. The great thickness of most of the parietes as compared with their thinness in the fetus, Fig. 667.

D. The retention of the fetal tenuity of a portion of the mesal wall, viz., the hemiseptum (halves of the septum lucidum).

E. The considerable length and width of the human pseudocele (fifth ventricle); so far as I have observed it is wider than in any other animal; in Fig. 726 (of the sheep) it is unnaturally wide.

F. The relation of the cortex (cerebral ectocinerea) to the medulla (alba), as an ectal layer following the fissural indentations.

G. The relation of the insula to the Sylvian fissure; the former is a typical subgyre, the latter is a typical superfissure.

H. The relation of the claustrum to the insular cortex ectad and the lenticula entad (see also Fig. 782).

I. The constitution of the caudatum by two regions, a larger cephalic, the caput, and the cauda, narrow, and following the curve of the medicornu.

J. The junction of the occipital and calcarine fissures so as to constitute as it were a single bifurcate fissure.

K. The size and distinctness of the collateral eminence, an ental elevation or colliculus, corresponding to the collateral fissure upon the ventro-mesal aspect of the cerebrum.

L. The existence, on the left, of an elevation, the occipital eminence, corresponding with the occipital fissure. This colliculus is distinct in the fetus (Figs. 734 and 761), and in some adults (Fig. 744) is better marked than in this specimen.

M. The location of the portas (foramina of Monro), and their visibility in a direct dorsal view of the paraceles; by reference to Figs. 720 and 724, it will be seen that each porta opens into the corresponding paracele obliquely, looking laterad, cephalad, and also dorsad; hence it is visible from three different directions at right angles with one another.

N. The distance between the two portas. Deducting the slight length of the passages themselves, this distance represents the width of the aula, the mesal division of the prosocele, which is commonly reckoned as merely the cephalic part of the "third ventricle."

O. The continuity of the hemiseptum, a part of the mesal wall of the paracele, with the fimbria, a part of its floor; indeed, their topographical relations may be illustrated by bending a sheet of paper or metal, and holding it so that one portion is vertical and the other nearly horizontal; the former will represent the hemiseptum, the latter the fimbria.

P. The narrowness of the human fornix as measured by the distance between the lateral margins of the two fimbrias in their horizontal portions: compare the sheep, Fig. 726. It is true the word *fornix* does not occur on the figure; but, as discussed in § 197, the fornix is constituted by the two hippocamps, with their fimbrias, united at the meson by the commissure (Fig. 732); in this dissection the commissure is invisible, being upon a lower plane, so the fornix, as a whole, cannot be indicated.

Q. The smallness of the paraplexus as compared with its fetal condition, Figs. 667 and 747.

R. The formation of the free margin of the paraplexus by the medicornual vein, considerable in size and more or less contorted, by which the blood of the plexus is returned to the velar vein.

S. The considerable width of the attached portion of the paraplexus. This appears on the left side where the plexus has been trimmed quite closely. The rima is the line of apparent interruption of the parietes for the intrusion of the paraplexus, and is unusually wide in this specimen.

T. The completeness of endymal continuity and celian circumscription. These terms have been discussed in §§ 63–66, as exemplified upon the mesal aspect of the brain, Fig. 687. There only the mesal cavities are visible. In the present figure (aside from the pseudocele, which is not a true member of the series) there appear only the great lateral cavities of the prosencephal. The continuity of the endyma is represented by the uninterrupted heavy line surrounding either paracele. Likewise is the endyma a continuous sheet upon the sides and floor of this cavity. At the margins of the rima it may be traced as a smooth surface upon the intruded paraplexus, and its cut edges are represented on the left in this figure. I am aware that several authors claim or admit the existence of orifices along the medicornu whereby the neurolymph may escape therefrom into the adjacent subarachnoid space; but I am compelled, at present, to regard these as artifacts, like the half-dozen ruptures of the endyma near the porta in the preparation shown in Fig. 721.

U. The *apparent* entrance of the thalamus into the composition of the floor of the paracele. This condition is presented on the left side; on the right it is hidden by the overlapping paraplexus.

§ 197. *Fornix* is a collective noun, a comprehensive name applied to a congeries of parts, each of which has its own name, and all of which, with a single exception, may exist in lower vertebrates and in man or other mammals, in certain anomalies, without the formation of the fornix as a whole.

§ 198. *Columns of the Fornix.*—In each hemicerebrum there is a bundle of fibres ascending from the albicans and thalamus, passing just caudad of the precommissure, forming the cephalic boundary of the porta, diverging presently from its opposite, pursuing a curved direction along the floor of the medicornu and ending in the temporal lobe; in the aulic region, where it is most compact and exposed, this is commonly called an "anterior pillar of the fornix"; see Fig. 739.

§ 199. *Hippocamp* ("*hippocampus major*").—In each hemicerebrum there is a corrugation of the entire thickness of the parietes, resulting in the formation of a total fissure, the hippocampal (§ 259, C), and an ental elevation, or colliculus, the hippocamp, along the medicornu; the hippocamp is thickened also, and intimately associated with the fibres of the column already mentioned.

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* The paper of E. A. Spitzka (1900) will contain an account of the topographic relations of the paraceles to the cerebral surfaces.

(Fig. 735.) 1, Cut surface, extending meso-ventro-cephalad; 2, cut surface of the genu, the cephalic curvature of the callosum; part of its natural, pial surface lies just cephalad; the transverse lines on the areas 2 and 9 are introduced merely to indicate the direction of the callosal fibres, not as representations of microscopic structure; 3, point of disappearance of the pia as a result of cutting away part of the lateral convexity of the cerebrum; 4, meeting-place of the two oblique cut surfaces caused by the exposure of the medicornu; 5, point of reappearance of the pia, which was interrupted at 3; 6, is an area just caudad of the left calcarine fissure; 7, the occipital fissure; 8, the occipital eminence (see under *Defects*); 9, oblique cut surface of the splenium, of which a part of the natural surface is shown just caudad; 10, the cut edge of the paratela covering the thalamus; from 10 a line should pass mesad to the narrow area between the two lines.

Defects.—The alcohol had so bleached the cinerea as to render the recognition of its outlines somewhat difficult, so the width of the cortical zone is only approximately accurate.

The absence of shading upon the larger part of the surface would imply that it is all upon one level; really, however, the highest part corresponds nearly with the length of the exposed portion of the right caudatum, and from that level there are gentle slopes cephalad, caudad, and laterad. The cut edges of the hemiseptums are also at a lower level than the adjacent lateral parietes. Not all of the arteries are represented. The occipital eminence (8) is indistinct upon the right and made too small upon the left. The cut edge of the paratela (10) is made too thick and the relations of parts are indistinct (see § 191).

On the left, near the word *fimbria*, is a defective patch of shading due to a blemish in the paper.

The arachnoid is represented distinct from the pia at only two places, viz., on the right, near the cephalic end, where the former crosses the wide mouth of a fissure, while the latter dips into it as a fold, and at the collosal fissures, just caudad of the splenium.

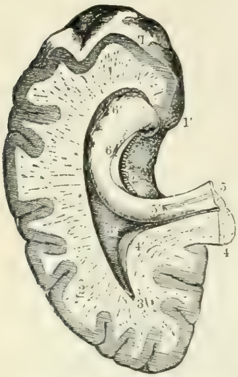

FIG. 736.—The Left Hippocamp and Adjoining Parts. × 5. (From Quain, altered from Hirschfeld and Leveillé.) 1, Apex of the temporal lobe; 1′, uncus; 2, cut surface of the cerebral medulla surrounded by the cortex; 3, at the apex of the postcornu; 3′, collateral eminence; 4, part of the splenium, nearly medisected; 4′, points to the calcar; 5, cut end of the lateral portion of the fornix which is continued at the hippocamp (5′) and the fimbria (6); 6, the fimbria; 6′, the terminal expansion of the hippocamp, called *pes hippocampi*; 7, dentate gyre ("*fascia dentata*").

Preparation.—The left occipitotemporal region of the cerebrum was separated from the rest, together with a part of the splenium and fornix, and the dorsal and lateral parietes of the postcornu and medicornu sliced away so as to expose nearly the entire extent of the cavities.

Defects.—The specimen had not been alinjected, and the figure looks somewhat diagrammatic, especially as to the dentate gyre (7); the actual extremity of the medicornu does not appear (see Fig. 728). There is no indication, along the free margin of the fimbria, that one surface of this lamina was covered by pia and the other by endyma, and that they were continued in and upon the removed paraplexus.

§ 200. *Fimbria.*—In each hemicerebrum between the hippocamp, with its corresponding cortex, and the rima, or line of intrusion of the paraplexus, there is a zone consisting of alba alone, and forming, as it were, a margin for the hippocamp (Figs. 733, 735, and 759). This is the fimbria (*corpus fimbriatum, tænia hippocampi*).

§ 201. The column and its caudal, curved extension, the hippocamp and the fimbria, are simply portions of the prosocelian parietes, mainly of the paracelian floor; they are continuous with the mesal wall, hemiseptum (Fig. 732), and thus indirectly with the roof (callosum); excepting at the ventral end, in the tip of the temporal lobe, however, their substantial continuity with the caudatum and tenia and other portions of the paracelian parietes is interrupted by the rima. It would be perfectly legitimate, therefore, to designate the irregular, elongated portion of either paracelian floor, composed of hippocamp, fimbria, and fornicolumn, by a special name, *e.g., hemifornix.*

§ 202. *Commissure of the Fornix.*—The parts composing either hemifornix pertain each to its own hemicerebrum, and in brains in which the callosum is undeveloped, these have no connection across the meson dorsad of the aula and portas, representing the primitive mesal cavity of the prosencephal. So far as I know, the fornicommissure is thinner in man than in any other mammal; Fig. 731.

§ 203. The fornix is monographed by Honegger in the *Recueil Suisse* (zoölogie), 1890, v., 311–434. The hippocamp has been treated by Alex. Hill, in a paper of which an abstract is published in the Royal Society Proceedings, vol. iii., p. 5. Variations in the form of the hippocamp and the collateral eminence are described by Howden in *Journ. Anat. and Physiol.*, xxiii., p. 283, January, 1888. J. G. MacCarthy has described an interesting feature of the hippocampal structure in *Journ. Anat. and Physiol.*, xxxiii., p. 76, 1898. In the same journal are several recent papers by G. Elliott Smith discussing instructively the fornix and the commissures generally.

§ 204. *Lyra.*—When the fornix is transected through the columns (Fig. 737) and turned caudad the exposed ventral surface, including the splenium, is seen to present lines which have been rather fancifully compared to the strings of a harp; the lyra is not a part, but merely a surface.

§ 205. *Fig. 737 illustrates:* A. The general form of the velum, a double fold of pia between the thalami and the superposed cerebrum, one of the layers belonging to each of the two segments (Fig. 710); the great veins are between the two, and others enter them from adjoining organs. The free lateral margins of the velum project into the paraceles as the paraplexuses (Fig. 720), and its rounded apex hangs in the aula and the two portas as the auliplexuses and portiplexuses (Figs. 721 and 724).

B. The triangular form of the fornix; the cephalic, or "ascending" part, consisting of the two parallel columns, constituting the so-called "anterior pillar"; it expands caudad, the sides being incurved instead of nearly straight, as with the cat, and at the splenium is quite wide. Each lateral half here is practically composed of the corresponding hippocamp and fimbria, which, as they continue along the medicornu, are sometimes called the "posterior pillar."

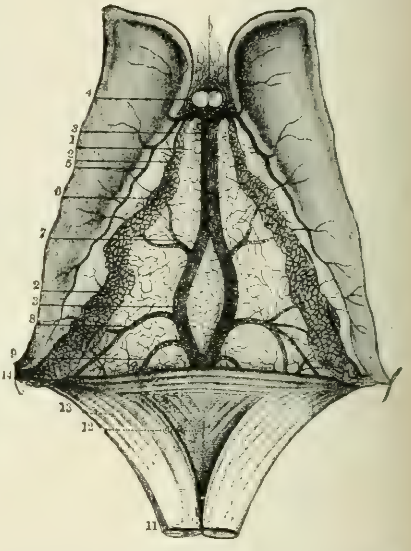

FIG. 737.—The Velum and Lyra. × 1.5. (From Quain, after Sappey and Vicq d'Azyr.) 1, The narrower cephalic part of the velum; 2, left paraplexus, the margin of the velum which enters the paracele as the paraplexus; 3, left velar vein, partly covered by the right; 4, columns, with small veins said to come from the callosum and septum, the precornual veins; 5, tenial vein; 6, medicornual vein; 7, thalamic vein; 8, vein from left medicornu; 9, postcornual vein; 11, body of fornix, transected and reflected; 12, lyra; 13, on the lateral part of the fornix; 14, splenium. (The names here employed for the veins are those adopted in the article *Brain, Circulation of*, in this volume.)

Preparation.—With a preparation such as is represented in Fig. 735, if the fornix were transected at its middle (*f*), the caudal half turned caudad, and the cephalic half, with the attached hemiseptums, removed down to the middle of the height of the portas, the appearances would be nearly as in the present figure.

Defects.—The relation of the parts shown to the rest of the brain would be clearer if there were included at least an outline of one side or of the adjoining region. The tenias are omitted, between which and the fornical margins, fimbrias, the paraplexuses enter; at the mesal side of each paraplexus should be a line, a ripa, indicating where the endyma covering the plexus was torn or cut in the separation of the fimbria. The whole, especially the lyra, is somewhat idealized.

C. The nature of the lyra (§ 204). The line from 12 ends at the meson, the location of the fornicommissure or thin part connecting the thicker lateral portions.

D. The double relation of the splenium to the callosum and the fornix. The larger part, body, of the callosum consists of fibres which pass laterad, dorsad of the paraceles, constituting their roof; at the splenium some fibres pass dorsad, some caudad, some ventrad, and others in intermediate directions; now all the constituents of the fornix form parts of the floors rather than the roofs of the paraceles, and at the splenium fornix and callosum become continuous.

§ 206. *Modifications of the Prosocelian Parietes.*—Primarily the cerebrum is a pair of lateral extensions of a small mesal rudiment, the first (cephalic or "anterior") encephalic vesicle; this forms their only bond of union with one another and with the other segments; their walls are thin and vary little in thickness or composition. Secondarily, the two hemicerebrums are closely conjoined by the callosum and other commissures; between the cerebrum and the crura (and thus the oblongata, the myel, and indirectly the entire body) are developed extensive fibrous communications, the capsulas or "internal capsules"; the parietes are, for the most part, extraordinarily thickened, the most notable, and physiologically the most important of these increments constituting what are commonly called the "corpora striata," from the appearance presented on sections of alternating strips of alba and cinerea. Each striatum, however, is now recognized as composed of an entocelian ("intraventricular") portion, the caudatum, and an ectocelian ("extraventricular") portion, the lenticula ("lenticular", or "lentiform nucleus"), separated by the capsula already mentioned (Figs. 739 and 782).

§ 207. *The Caudatum and Lenticula.*—With all Reptiles, Birds, and Mammals, and at a very early period, the lateral wall and floor of the paracele present a more or less distinct elevation; in man, and some other mammals, the form is such as to suggest the application of *caput* to the cephalic (precornual) portion, and *cauda* to the tapering continuation along the medicornu, thus of *caudatum* to the entire mass (Fig. 735).

Between the caudatum and the cortex the greatly thickened hemicerebral wall presents (*a*) the medullary lamina called *capsula* (§ 208); (*b*) next the cortex, a subcircular disc of cinerea, the *claustrum* (Figs. 739 and 782); and (*c*) the *lenticula*, consisting of three zones, all more or less striated, the ental the smallest, and the ectal, also called *putamen*, the largest. The lenticula, like the claustrum, may be a dismemberment of the cortex. This entire region, from caudatum to operculums, is of great morphological as well as physiological interest and should be studied in the other mammals.

§ 208. *Capsula and Corona.*—As already stated (§ 206) the capsula or "internal capsule" is the thick layer of fibres between the caudatum and thalamus mesad and the lenticula laterad; it is continuous with the crura caudad, and expands in the substance of the cerebral alba in such a way as to be called there *corona* (*radiata*). The histological and physiological aspects of the capsula and corona are considered in other articles; here an attempt will be made to indicate only their topographical relations by explanations of the accompanying figures (738 and 739).

§ 209. *Fig. 738 illustrates:* A. The general relations of the alba (medulla) to the ectocinerea (cortex).

B. The locations of the two great masses of entocinerea (central tubular gray), the caudatum and the thalamus.

C. The intermediate position of the lenticula, as a blunt wedge-shaped mass between the caudatum and thalamus.

D. The position of the capsula ("internal capsule") as a stratum of alba between the lateral lenticula and the other two masses, and constituting a fibrous path for motor and sensory conduction between the cortex and the crura.

E. The existence of two zones in the lenticula, the more lateral being distinguished as *putamen;* a third would have appeared at a level farther ventrad (Fig. 739).

F. The existence of a thin, cinereal lamina ectad of the lenticula, between it and the cortex; this is the claustrum; it and the cortical corrugations of this region are shown upon a larger scale in Fig. 782.

§ 210. *Fig. 739 illustrates:* A. The existence and relative positions of four important masses of connecting fibres, the *callosum, columns of the fornix, precommissure,* and *chiasma,* differing from one another in either their direction or their appearance upon this section. The most ventral, the chiasma, is mainly a decussation, as described in the article *Cranial Nerves.* The next, precommissure, is a true commissure, connecting corresponding regions of the temporal (and frontal?) lobes; at the meson it is seen as a raised transverse band, but laterad, on account of its deflection caudad, it is divided obliquely, and appears as an elliptical dotted area. The two columns have at this level a nearly dorso-ventral direction, appearing as raised bands just dorsad of the precommissure (the line from the word *aula* ends upon the right), but they are curved in such a way as to be divided obliquely in two places—one at the level of the precommissure, and the other about 1 cm. (on this scale) dorsad. Finally the callosum, a true commissure, uniting corresponding regions of the cerebrum, is divided in the direction of its fibres.

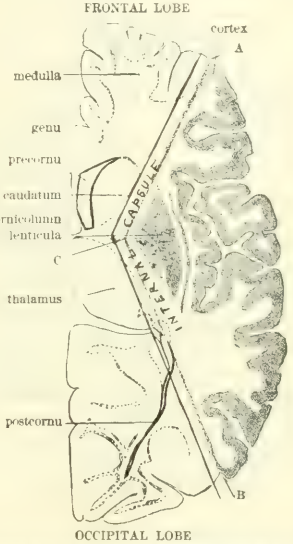

FIG. 738.—Longisection of the Right Hemicerebrum at the Level of the Aula. × .05. (From nature [2,397] and from Gray.)

Preparation. The mesal outlines of the removed frontal and occipital regions were adapted from Gray. The plane of section corresponds nearly with the direction of the dotted line from *aula* on Fig. 739. The line *A, B, C* should have been dotted. This line and the one parallel with it mesad by the "internal capsule" were introduced with reference to another figure which is not given here.

B. The general relation of parts and cavities at this important level. Two segments are represented—the diencephal (thalami, chiasma, and diaterma) and prosencephal (the remaining and much the larger part). Of the cavities, the mesal space between the chiasma and precommissure is the cephalic part of the diacele, the darkest portion being the optic recess. The prosocele is represented by the *aula,* the mesal space dorsad of and including the precommissure; by the considerable lateral cavities, *paraceles;* and by the intervening *portas.* All these are true encephalic cavities, but the dark triangular area still farther dorsad is the pseudocele.

Three kinds of surfaces are included, viz.: entocelian, lined by endyma; ectocelian, covered by pia; and pseudocelian, with no distinct membrane. There is ectocinerea (cortex), entocinerea (caudatum and thalami), and what may, for the sake of a general term, be called *medicinerea*, the lenticula, and the claustrum, probably dismemberments of the ectocinerea.

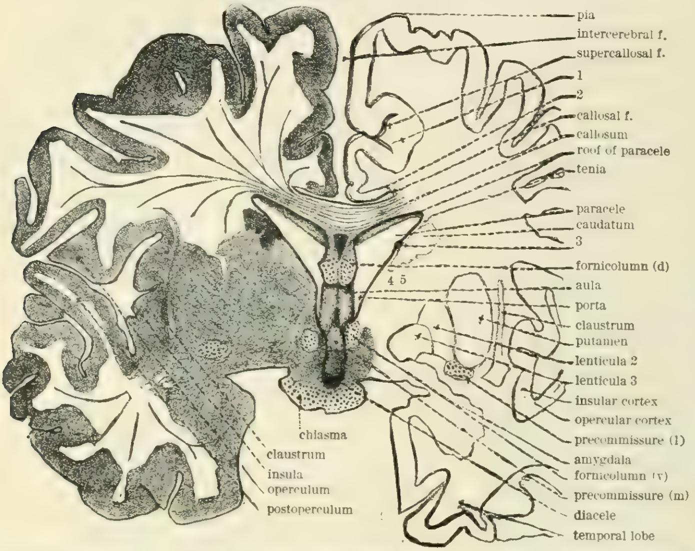

FIG. 739. Transection at the Chiasma and Precommissure, Caudal Aspect. (From Dalton, by permission.) Reduced one-sixth and modified (compare Figs. 724, 738, and 782). 1, A subgyre (covered gyre) at the bottom of the supercallosal fissure; 2, margin of the cortex dorsad of the callosal fissure; 3, tenial vein; 4, the cephalic part of the thalamus, faintly outlined on the other side; 5, capsula.

Defects.—The dots representing cut fibrous areas are too heavy. The lines representing the callosal fibres are diagrammatic; one of them is interrupted. The pseudocele is not specified. The area cf the thalamus is too vaguely indicated. See § 210.

C. The extension of the hemicerebrum nearly equally in three directions from the place of its morphological centre, the porta; were this brain not somewhat depressed by its own weight, the width and height would be nearly the same.

D. The thickness of most of the parietes as compared with the earlier fetal conditions shown in Figs. 667 and 716; the hemiseptums and the terma, however, have retained their tenuity in great degree.

E. The absence of the crista which was seen in a young brain (Fig. 793), and is constant in the cat (Fig. 686); whether it is absorbed or merely obscured in the human adult is not known (§ 366).

F. The overlapping of the prosencephal at the sides of the diencephal, of the cerebrum upon the thalami.

G. The relations of the several layers of alba and cinerea between the thalamus and the lateral surface of the cerebrum. The capsula (5) has an oblique direction, dorso-laterad, between the thalamus and caudatum and the lenticula (see Fig. 738). The lenticula itself comprises three more or less distinct segments, each extending farther dorsad than the one mesad of it; all present the alternating lines of white and gray which led to the application of *striatum* to the united lenticula and caudatum. The thin lamina of cinerea between the putamen, the most lateral division of the lenticula, and the insular cortex is the claustrum, and the alba between it and the lenticula is commonly, but inappropriately, called the "external capsule."

H. The relations of the insula to the parts just named, and to the overlapping gyres which constitute the operculums (see Fig. 782).

I. The relation of the cinereal mass called *amygdala* to a fissure opposite the *m* of *postoperculum*, which has thence been called the amygdaline fissure; but it is doubtless homologous with the postrhinal of quadrupeds. (§ 372, Fig. 765.)

§ 211. Besides the precommissure, a medisection displays two extensive lines of cut surface (Figs. 670, 682, 687, and 765), indicating that there was a continuity of the apposed, mesal surfaces of the two hemicerebrums. Of these the dorsal, more extensive and more substantial, is the *callosum* (Figs. 724, 737, 739, and 740); the ventral is the *commissure of the fornix* (Figs. 732 and 743).

§ 212. *Callosum.*—When the fresh hemicerebrums are divaricated, as in Fig. 740, the bottom of the intercerebral fissure is seen to be formed by a white mass which unites them for more than the middle third of their length; upon hardened brains this, the callosum (*corpus callosum, trabs cerebri*, etc.), is easily determined to be fibrous, and somewhat firm in consistency, and to extend into the hemicerebral masses. At about the middle of its cephalo-caudal extent, the trend of the callosal fibres is almost directly laterad, but at the cephalic and caudal ends, especially the latter, the direction is oblique, giving rise to the conditions known as *preforceps* and *postforceps* (Figs. 735 and 740). The rounded cephalic region of the callosum is the *genu*, and the caudal, the *splenium*. As seen in medisections (Figs. 670, 687, and 743) the genu appears like a folding of the callosum upon itself, the ventral continuation being the *rostrum*, which, in man and other primates, is connected with the terma by the thin *copula*. The gentle curve of the genu gives to the cephalic part of the pseudocele a rounded outline.

§ 213. *Fig. 742 illustrates:* A. The primary continuity of the hippocampal and callosal fissures, and of the frontal extension marked 1.

B. The existence of several early fissures, some of which are probably transitory.

C. The continuity of the callosum, fornix, and terma.

D. The degree of separation of the callosum and the fornix at this period, and the concomitant form and extent of the pseudocele.

§ 214. *Splenium.*—This region of the callosum is much less easy to understand than the genu from the study of normal adult brains, but most of the difficulties are removed or diminished by the study of fetal and hydrocephalous specimens (Figs 742 and 743). From these it is clear that, like the genu, the splenium represents a flexion of the callosal sheet upon itself so that there is a dorsal lamina, a ventral lamina, and a caudal connecting portion; commonly the dorsal and ventral portions are in close contact, but in hydrencephals (Fig. 743), as in the fetus at a certain stage, they are separated by a considerable interval; in these cases the pseudocele has a greater extent and a somewhat rounded caudal end. For the most part the callosum extends dorsad of the paraceles, thus constituting their actual (though not primary) roof; but the fibres extending obliquely cephalad and caudad from the genu and splenium are parts of the mesal wall of the precornu and postcornua respectively, while those which compose the ventral lamina and the splenium are parts of the paracelian floors, continuous with the fornix (Figs. 733 and 744).

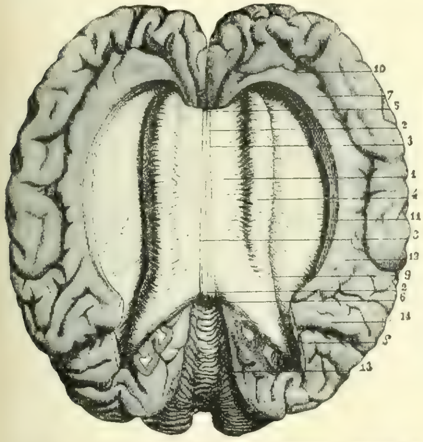

FIG. 740.—The Dorsal Aspect of the Callosum, Exposed by Divaricating the Hemicerebrums. (From Quain, after Sappey and Foville.) × 0.5. 1, Dorsal surface of the body of the callosum; 2, mesal ridge or raphé; 3, lateral ridges, bounding furrows in which, sometimes at least, are lodged the precerebral arteries; 4, lateral ridge, said to be formed by the arching of the callosum over the paracele; 5, cephalic curved margin, genu; 6, caudal curved margin, splenium; 7, preforceps, callosal fibres passing cephalad into the frontal lobes; 8, postforceps, fibres entering the occipital lobes; 10, cephalic portion of the callosal gyre, the line crossing the cephalic end of the supercallosal fissure; 11, callosal fissure; 12, caudal part of the callosal gyre, the line crossing the paracentral gyre; 13, cephalic surface of the cerebellum, the number being just caudad of the occipital fissure.

Preparation.—While fresh the dorsal portions of the hemicerebrums were separated widely; the curved margin of the callosal gyre ("*gyrus fornicatus*") has been detached and pushed laterad so as to expose more completely the extension of the callosal fibres into the hemicerebrum; caudad this gyre has been divided. See § 212.

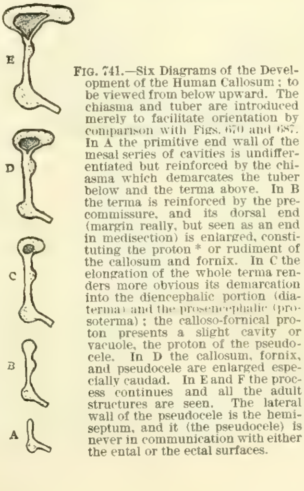

FIG. 741.—Six Diagrams of the Development of the Human Callosum; to be viewed from below upward. The chiasma and tuber are introduced merely to facilitate orientation by comparison with Figs. 670 and 687. In A the primitive end wall of the mesal series of cavities is undifferentiated but reinforced by the chiasma which demarcates the tuber below and the terma above. In B the terma is reinforced by the precommissure, and its dorsal end (margin really, but seen as an end in medisection) is enlarged, constituting the proton * or rudiment of the callosum and fornix. In C the elongation of the whole terma renders more obvious its demarcation into the diencephalic portion (diaterma) and the prosencephalic (prosoterma); the calloso-fornical proton presents a slight cavity or vacuole, the proton of the pseudocele. In D the callosum, fornix, and pseudocele are enlarged especially caudad. In E and F the process continues and all the adult structures are seen. The lateral wall of the pseudocele is the hemiseptum, and it (the pseudocele) is never in communication with either the ental or the ectal surfaces.

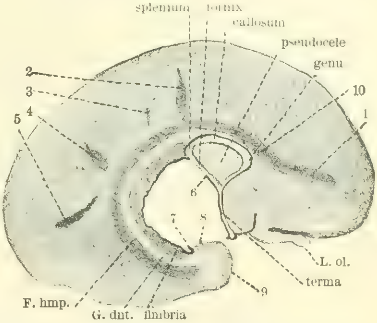

FIG. 742.—Mesal Aspect of the Left Hemicerebrum of a Fetus, Measuring 16.8 cm. from Heel to Bregma, and Estimated at Eighteen Weeks; 2,084. × 1.5. 1, Cephalic extension of the primitive callosal fissure; 2, 3, 4, 5, short but distinct radial fissures, some of them probably transitory; 6, point of reflection of the endyma from the fornix at the dorsal end of the porta; 7, point of reflection of the endyma at the tip of the rima upon its other margin, the tenia, which has been removed; 8, region which would have become the uncus; 9, tip of the temporal lobe; *F. hmp.*, the hippocampal fissure; *G. dnt.*, the dentate gyre (*fasciola* or *fascia dentata*); *L. ol.*, olfactory bulb.

Preparation.—The fetus was ill preserved and the head distorted; the entire head was medisected with a scalpel; the brain was so tender that the caudatum and plexus broke loose.

Defects.—The terma is shown too thick; the tenderness of the specimen did not permit determining the location and form of the chiasma and precommissure.

§ 215. *Fig. 743 illustrates:* A. The complete separation of the fornix and callosum as far as the splenium, which is thus a common bond between them, although usually, and perhaps properly, reckoned as a constituent of the callosum only.

B. The concomitant extension of the pseudocele and of the hemiseptum.

C. The large size of the porta.

D. The wasted appearance of the visible gyres, in contrast with those of Chauncey Wright (Fig. 788).

§ 216. *Fig. 744 illustrates:* A. The continuity of the splenium with both the floor, roof, and caudo-mesal wall of the paracele; some of the fibres pass dorsad, some ventrad into the hippocamp, while others, constituting the postforceps, extend caudad into the calcar, dorso-caudad into the occipital eminence, and ventro-caudad into the collateral eminence.

B. The unusual distinctness of the occipital eminence, this being, in fact, the preparation in which it first attracted my attention (comp. Fig. 761).

C. The prominence of the calcar, here seen, of course, greatly foreshortened; of the left hippocamp only a segment of the caudal convexity appears in this preparation, with the collateral eminence just beyond (compare Fig. 735).

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* This neuter noun is employed to designate the primitive, undifferentiated mass or rudiment of a part, thus in the sense of *Anlage* of the German embryologists (as adopted by Minot and others), and of *fundament*, as proposed by Mark ("Comparative Embryology"). It avoids certain obvious objections to those terms as English words, is shorter than *primordium* (proposed by Willey), and is in harmony with the following phrases from Aristotle, kindly quoted by President B. I. Wheeler: τὸ πρωτον; ἡ πρωτη ὑλη; ἡ πρώτη αἰτια.

§ 217. *Indusium.*—This term (coupled with the adjective *griseum*) was given by Obersteiner (1892, p. 82) to the thin layer of cinerea upon the dorsal surface of the callosum. It has been discussed by Giacomini, Blumenau, and more recently by Fish, 1893, *a*.*

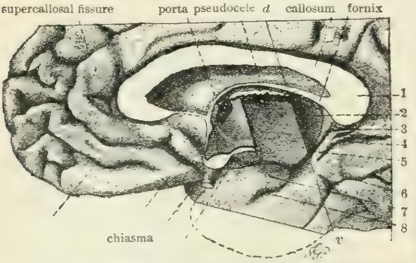

FIG. 743.—Mesal Aspect of Part of the Right Hemicerebrum of an Adult Hydrocephalus; 747. × .7. The dorso-ventral line, *d v*, indicates the transection plane represented in Fig. 731. 1, Splenium; 2, ventral surface of fornix; 3, subsplenial gyres; 4, 5, ?; 6, collateral fissure; 7, uncus; 8, hippocampal fissure. The tip of the temporal lobe, included by the interrupted line just cephalad of *v*, indicates what was removed to expose the parts shown in Fig. 728.

§ 218. In several (perhaps half a dozen) brains in the Cornell museum the callosum presents a decided thinning at about the junction of the middle with the splenial third; most if not all of the individuals were mentally defective in some degree.

§ 219. *Incallosal Brains.*—In addition to about fifteen cases of shortness or thinness of the callosum, there have now been reported at least a dozen instances of its complete absence, together with the mesal part of the fornix. Commonly this deficiency was accompanied with mental and physical weakness, amounting often to idiocy; but Malinverni reported (*Giornale del R. Acad. Torino*, 1874; *Gazette médicale de Paris*, January 16th, 1875; *Gazetta delle Cliniche*, 1874, No. 15; *London Medical Record*, 1874, No. 73) the case of a soldier, forty years of age, who had been noted merely for melancholy, taciturnity, and lack of neatness. A case of total absence of the callosum and fornix is described and figured with unusual fulness by Alex. Bruce, in *Brain*, xiii., 171–190. There are included abstracts of previous cases and reduced copies of the illustrations of some.

§ 220. *Fig. 745 illustrates:* A. The absence of the callosum and of the commissure (mesal part of fornix).

B. The development of the columns as far dorsad as a point corresponding apparently to the dorsal limit of the aula and porta (which is not distinctly indicated).

C. The roofing in of the aula and diacele by a thin (membranous?) tela, the remnant of the primitive roof of the cavities.

D. The absence of the medicommissure and small size of the precommissure, in contrast with the same parts in the incallosal cat (§ 221).

E. The independence of the occipital fissure, and the *apparent* junction of the calcarine with the hippocampal.

F. The radial disposition of the mesal fissures; some of them probably represent the transitory fissures mentioned in § 227.

§ 221. Among other mammals than man the total absence of the callosum has been observed, so far as known to me, only in three cats examined in the anatomical laboratory of Cornell University; one of these (No. 381) has been described in my paper (1883, *c*), and was represented in the first edition of the REFERENCE HANDBOOK, Fig. 4,835. At the Boston meeting of the Association of American Anatomists, December 29th, 1890, I showed the brain of a sheep (No. 2,844) in which the callosum is represented, if at all, by a short thin lamina; but this specimen, fortunately unmutilated and thoroughly hardened, has not yet been figured or described.

§ 222. *Pseudocele* ("*fifth ventricle*," "*ventriculus septi pellucidi*").—This compressed, subtriangular mesal cavity has no connection with the true encephalic cavities either in the adult or at any stage of development. Its anatomical relations are shown in Figs. 687, 732, 735, and others; but they are more clearly understood from the series of diagrams in Fig. 741 based upon my own specimens and the account of Marchand ("Ueber die Entwickelung des Balkens im menschlichen Gehirn," *Archiv für mikr. Anat.*, xxxvii., pp. 298–334).

§ 223. In the cat (Fig. 682) and mammals generally, both the anatomical and developmental conditions are different. The fornix commissure and the callosum constitute portions of two lines of secondary junction of the two hemicerebrums and are continuous at the splenium

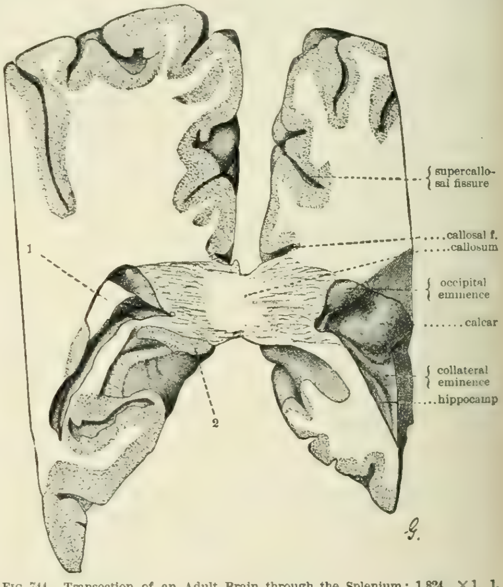

FIG. 744.—Transection of an Adult Brain through the Splenium; 1,824. × 1. 1, Postcornu; 2, section of a subsplenial gyre.

Preparation.—The brain was that of a Pole, male, and was received in the head through the kindness of Dr. F. Cary, a former student. With the special object of furnishing reliable preparations for the elucidation of the celian parietes (see Fig. 732), the sides of the head were sawn off so as to expose the medicornu, and into this was injected a mixture of alcohol (95°) and water, each 2 litres, ammonium dichromate, 10 gm.; the same was injected into the arteries. When the brain was completely hardened it was removed and transected at intervals of about 1 cm.

Defect.—The lines representing the callosal fibres should be continued across the meson.

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* I have to record with some chagrin that, upon a series of transections of an adult brain (1,824), sections of which are shown in Figs. 732 and 744, hardened in a mixture of ammonium dichromate and alcohol, the continuity of the cinerea upon the callosum was recognized in October, 1880; notwithstanding its significance, further examination and publication were deferred.

as in man; but cephalad the callosum ends as a point so that the triangular area is not completely circumscribed; commonly, also, the interval corresponding to the pseudocele is narrower than in man.

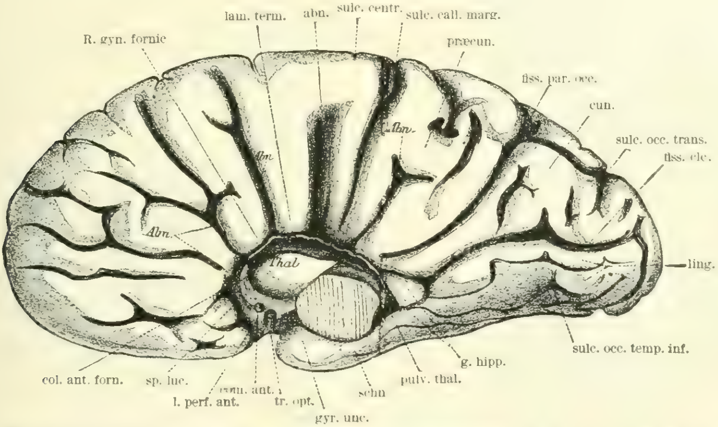

FIG. 745.—Mesal Aspect of the Right Hemicerebrum of an Incallosal, Microcephalic, Adult Brain. × .93. (From Onufrowicz.) *Abn.*, abnormal radiating fissures; *Col. ant. forn.*, fornicolumn; *Com. ant.*, precommissure; *Cun.*, cuneus; *Fiss. clc.*, calcarine fissure; *Fiss. par. occ.*, occipital fissure; *G. hipp.*, hippocampal gyre; *G. unc.*, uncus; *L. perf. ant.*, precribrum; *Lam. term.*, terma [aulatela and diatela]; *ling.*, subcollateral gyre; *praecun.*, precuneus; *Pulv. Thal.*, pulvinar (of the thalamus); *R. gyr. fornic.*, margin of the callosal gyre (*gyrus fornicatus*); *Schn.*, cut surface between the diencephal (thalami, etc.) and mesencephal (gemina); *Sp. luc.*, hemiseptum [?]; *Sulc. call. marg.*, supercallosal fissure [?]; *Sulc. centr.*, central fissure; *Sulc. occ. temp. inf.*, collateral fissure; *Sulc. occ. tr.*, "transverse occipital fissure" [?]; *Tr. op.*, optic tract.

Preparation. This was the brain of a male idiot, thirty-seven years of age, who had never learned even to feed himself; it seems to have been obtained fresh early and well preserved; the paper ("Das balkenlose Mikrocephalengehirn Hofman," *Archiv für Psychiatrie*, 1887, xviii., pp. 1–24) from which the figure is taken is by Onufrowicz, but this and most of the other figures are by Forel. There are several transections, but the lack of distinct indication of endymal continuity renders them less instructive than they might have been. The weight of the entire brain is not stated. See § 220.

§ 224. In three apes (orang, gorilla, and chimpanzee*) and in all the monkeys examined by me the conditions are as in man; the mode of development is not known to me.

§ 225. To English-speaking anatomists interested in the morphology of the cerebral fissures and commissures are particularly commended the recent writings of D. J. Cunningham, and G. Elliot Smith in the *Journal of Anatomy and Physiology.*

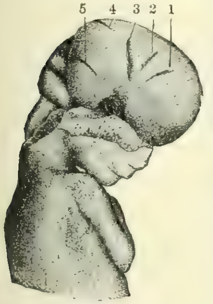

FIG. 746.—Right Side of the Brain of a Fetus Measuring 49 mm. from Nates to Bregma, and Estimated at Twelve Weeks; 1,828. × 1.4. (The left side of the same is shown in Fig. 673, where the mode of preparation is described.)

§ 226. *Fig. 746 illustrates:* A. The condition and relative size of the encephalic segments at this period.

B. The presence of transitory fissures which are absent from the other hemicerebrum (Fig. 673).

C. The indication, so far as these transitory fissures are concerned, that in this individual the right hemicerebrum was more advanced than the left.

§ 227. *Transitory Fissures.*—During the third and fourth months both the lateral and mesal surfaces of the cerebrum present linear depressions corresponding with ental ridges and thus representing corrugations of the wall (Fig. 747). They do not branch. Their general direction is radial. By the end of the fourth month they disappear from the lateral surface (Fig. 748) and partly at least from the mesal, although there is reason to believe that two of them may be practically perpetuated by the formation of the permanent calcarine and occipital fissures along the same lines (Fig. 730).

§ 228. *Fig. 747 illustrates:* A. The great size of the paraceles and paraplexuses at this stage; compare Fig. 667.

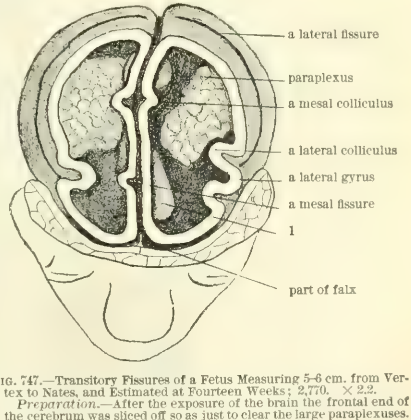

FIG. 747.—Transitory Fissures of a Fetus Measuring 5–6 cm. from Vertex to Nates, and Estimated at Fourteen Weeks; 2,770. × 2.2.

Preparation.—After the exposure of the brain the frontal end of the cerebrum was sliced off so as just to clear the large paraplexuses. Of the falx all was removed excepting the fragment shown. The head was tilted so that the face is much foreshortened.

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* A gibbon brain has not yet been available.

B. The slight and nearly uniform thickness of the parietes.

C. Suggestion of a wrinkling or corrugation of the parietes as if from growth within a confined space.

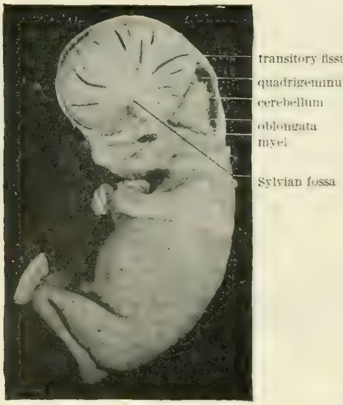

Fig. 748.—Fetus Measuring 7 cm. from Nates to Vertex, and Estimated at Fourteen Weeks; 2,761. × .9. Neg. 1,080. Received in weak alcohol and injected through the umbilical vein with alcohol and zinc chloride.

D. The approximately symmetrical distribution of these corrugations.

E. The length of the fissure on either side, reaching from the Sylvian fossa nearly to the meson.

F. The absence of any indication of branching.

§ 229. *Fig. 748 illustrates:* A. The large number of transitory fissures at this stage.

B. Their general arrangement as radiating from the Sylvian fossa; compare, however, Fig. 747.

C. The considerable difference in their length; one of the longest is indicated by the line from "transitory fissure"; one of the shortest is just below it.

§ 230. *Transitory Fissures Probably Mechanical in their Origin.*—The simplest explanation seems to be that their formation is due to the growth of the cerebral walls at a rate more rapid than that of the cranium; and that their disappearance results from the yielding or more rapid growth of the cranium.

§ 231. *Fig. 749 illustrates:* A. The disappearance of the transitory fissures, at least upon the lateral aspect.

B. The concomitant increase in the length of the cerebrum, apparently from the development of the occipital region; compare Figs. 667 and 673.

C. The non-appearance of the lambdoidal fissure (Fig. 750).

D. The commencement of the postoperculum as a fold of the temporal lobe projecting over the Sylvian fossa.

E. The non-appearance at this stage of the other operculums or of any elevation indicating the future insula.

§ 232. *Abnormal Persistence of Transitory Fissures.*—In several brains lacking the callosum (*e.g.*, the one shown in Fig. 745), the mesal permanent fissures present the radial arrangement characterizing the transitory fissures. This condition likewise exists upon the lateral aspect in the case described by Hans Virchow and shown by Cunningham (1892, Fig. 7).

§ 233. *Are Transitory Fissures Peculiar to the Human Brain?*—Hitherto, as remarked by Cunningham, they have been observed only in man. Before, however, concluding that they constitute a real human peculiarity they should be looked for in the other primates, where I believe they will be found at corresponding periods of development; the examination of the fetal gorilla described by Duckworth will be interesting in this respect. Cunningham has considered the transitory fissures quite fully, but the subject requires further investigation.

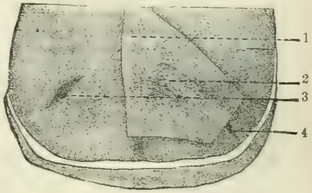

Fig. 750.—Dorso-Caudal Region of the Cerebrum of a Fetus Measuring about 30 cm. from Heel to Bregma, and Estimated at Six Months; 1,817. × 1. 1, Sagittal suture; 2, lambdoidal suture; 3, right lambdoidal fissure; 4, left lambdoidal fissure.

Preparation.—The entire fetus had been preserved in alcohol. From the left side the calva and dura were removed, excepting a narrow strip along the meson; on the right there was left a trapezoidal area, 12 to 25 mm. wide, including most of the sagittal and lambdoidal sutures.

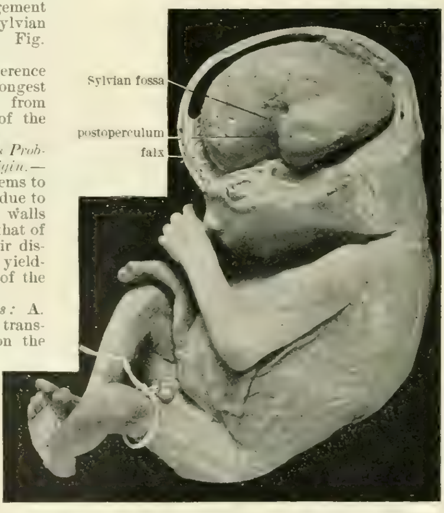

Fig. 749.—Fetus Measuring 8.8 cm. from Vertex to Nates, and Estimated at Four Months; 2,644. × .9. It is not very well preserved and the cerebrum is evidently shrunken.

§ 234. *Lambdoidal Fissure.*—In several fetuses estimated at from three to seven months I have observed a fissure directly underlying the lambdoidal suture (see Figs. 750 and 761, and my paper 1886, *a*). It is apparently identical with what are called by Cunningham "external calcarine" and "external perpendicular" (1892, *a*, Plates I. and II.); but I am unable to concur in his disposition of the matter or to decide whether the fissure disappears or persists (see Fig. 777).

§ 235. *Fig. 750 illustrates:* A. The distinct collocation of a fissure and suture at this period.

B. The early appearance (or late disappearance?) of this, the lambdoidal fissure; excepting, perhaps, the dorsal end of the occipital, the rest of this region is smooth.

C. The peculiar sharpness of outline, reminding one of the transitory fissures (Figs. 746 and 747; § 227).

§ 236. *Intercerebral Fissure.*—The interval between the apposed, mesal surfaces of the two hemicerebrums is the *intercerebral fissure* ("interhemispheral," "sagittal," or "great longitudinal") (Figs. 682, 707, and 739). It differs from ordinary fissures in the following respects: 1, It is mesal or azygous, while all others are lateral or in pairs; 2, although its sides are formed by cinerea, its bottom, the callosum, is apparently alba, with a comparatively thin layer of cinerea, the indusium, § 217; 3, although the pia has the usual relation, the arachnoid, instead of passing directly across, dips into it to a greater or less depth on account of the falx (Figs. 687 and 732); 4, it is, in one sense, a superfissure (§ 328) since in its depths are concealed the callosal fissures.

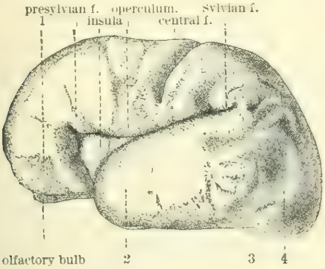

FIG. 751.—Left Fetal Hemicerebrum; 1,820. × 1. 1, Orbital region, unfissured; 2, temporal lobe, unfissured; 3, slight furrow, the preoccipital fovea; 4, circular depression, unidentified (see § 241).

Preparation. The fresh hemicerebrum was placed in a mixture of alcohol and glycerin, equal parts; after two days half the mixture was replaced by alcohol; after two days more alcohol alone was used, and renewed on the following day. The original mixture seemed to prevent the usual distortion of fetal brains, and to facilitate the removal of the pia. Unfortunately the age and size of the fetus were not recorded.

§ 237. *Poles and Lobes of the Cerebrum.*—The two ends of either hemicerebrum are distinguished as the frontal and occipital poles respectively, and the tip of the temporal lobe as the temporal pole. For topographical convenience, and not because they represent perfectly natural divisions, either anatomical, histological, or physiological, each hemicerebrum may be regarded as forming five lobes, the insula and the frontal, parietal, occipital and temporal lobes (Figs. 757 and 758). In a general way, but by no means accurately, the last four lobes coincide with the cranial bones for which they are named.

§ 238. The *insula* (*lobus opertus*, "central lobe") is nearly or quite covered in the adult brain by folds (operculums) from the adjoining lobes (Figs. 762 and 767); excepting at part of the ventral side the insula is surrounded by an irregular furrow, the circuminsular fissure (Figs. 781 and 782).

§ 239. The other four lobes have more or less complete natural boundaries on either the lateral or mesal surface, but not on both. The primary division is by the line of the central fissure (Fig. 751) into a frontal region and an occipito-temporo-parietal region. The former, although commonly accepted as a single lobe, is so extensive as to be conveniently subdivided by a line continued dorsocephalad from the presylvian fissure into a *postfrontal* and *prefrontal* lobe, the latter including the orbital surfaces.

§ 240. The region caudo-ventrad of the central fissure line is divided first by the occipital fissure into a *parietal* and an occipito-temporal portion, and the latter again into a *temporal* and an *occipital* lobe by artificial lines drawn from the preoccipital fovea, the indentation of the ventral margin corresponding with the petrous portion of the temporal bone (represented by the emargination opposite the word *collateral* in Fig. 757) to the splenium on the mesal aspect and on the lateral to the extremity of the Sylvian fissure.

§ 241. *Fig. 751 illustrates:* A. The early appearance of the Sylvian, presylvian, and central fisures, and of a depression which perhaps represents the beginning of the paroccipital. See the ventral surface of this specimen (Fig. 789).

B. The nearly uncovered and slightly fissured condition of the insula at this period; the faint dorso-ventral line just caudad of the end of the line from *insula* represents the just commencing transinsular fissure.

§ 242. *Permanent Fissures.*—The surface of the adult cerebrum presents alternating depressions, *fissures*, and elevations, *gyres* (or "convolutions"). The fissures vary in depth from 1 mm. to 30, and in length from 1 cm. to 10. The intervals between the fissures (and thus the width of the gyres) vary greatly, but an adult brain seldom presents an unfissured surface more than 20 mm. in width. Notwithstanding considerable variations in different brains, and in different parts of the same brain, one can hardly fail to be impressed with the approximate uniformity of the interfissural spaces (when viewed squarely, as suggested under Fig. 763), as if the fissures were produced mechanically by the extension of the surface within a confined space.

§ 243. *Fig. 752 illustrates:* A. The condition of the insula and operculums at this stage. The former is distinctly elevated, but as yet perfectly smooth, while in the otherwise less advanced brain shown in Fig. 751 it has a slight transinsular furrow. The subsylvian fissure is just forming as the ventral boundary of the preoperculum.

B. The demarcation of the subfrontal gyre by the subfrontal fissure.

C. The non-continuity of the parietal and paroccipital fissures.

D. The non-appearance of the precentral and postcentral fissures.

E. The peculiar triangular depression which seems to represent the commencement of the supertemporal fissure.

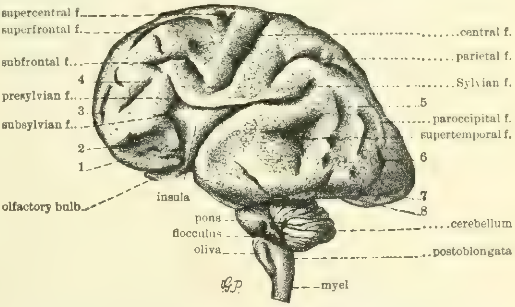

FIG. 752.—Lateral Aspect of the Left Half of the Brain of a Fetus, Size and Age Unknown; 2,278. × 1. 1-8, Fissures not identified with certainty. On the temporal lobe, just dorsad of the pons, the apparent fissure is an artificial crack.

Preparation.—The brain was medisected while fresh and this half placed in alcohol upon its mesal aspect; it has become thinner and wider than natural, but exhibits the fissures more perfectly on this account.

F. The presence of three fissures or series of fissures caudad of the supertemporal, the middle of which may represent the exoccipital (§ 344).

G. The interruption of the central fissure near its dorsal end; so much as appears in the figure is continuous, but near the mesal margin of the hemicerebrum is a slight depression separated from the longer lateral portion by an isthmus (comp. Fig. 772).

H. The small size of the cerebellum, the distinctness of the flocculus, and the prominence of the oliva.

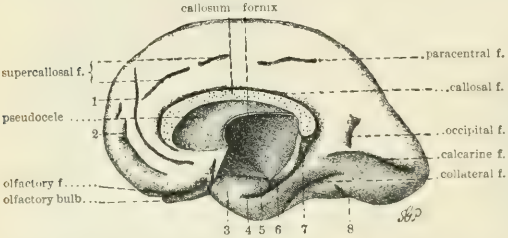

FIG. 753.– Mesal Aspect of the Left (Reversed) Hemicerebrum of a Fetus, Size and Age Unknown; 2,278. × 1. The lateral aspect of the left half of the same brain is shown in Fig. 752. 1, 2, Rostral fissures; 3, tip of temporal lobe; 4, ventral end of hippocampal fissure; 5, uncus; 6 (should have been extended a little farther so as to reach the light band), fimbria; 7, dentate gyre (*fascia dentata*); 8, undetermined fissure.

§ 244. A cerebral fissure is a narrow space vacant of brain tissue and containing only a fold of pia with blood-vessels; yet it has many and sometimes important relations, a complete account of which would embrace about fifty distinct topics. There are also about one hundred problems of a more or less general nature applying to several or all of the fissures.

§ 245. *Fig. 753 illustrates:* A. The existence of three independent furrows between the callosum and the margin of the hemicerebrum along the line of what is commonly called the calloso-marginal fissure.

B. The distinctness at this period of the four total or collicular fissures, occipital, calcarine, collateral, and hippocampal.

C. The independence of the occipital and calcarine.

D. The extension of the calcarine alone nearly or quite as far as the point reached in some other brains by the occipital alone or by the stem of the two. Sometimes the occipital is the longer in the fetus and occasionally, as in Fig. 754, union fails to occur.

§ 246. *Fig. 754 illustrates:* A. The complete separation of the calcarine fissure from the occipital by a calcarine isthmus. On the other side the two are connected as usual.

B. The bifurcation of the calcarine at each end, constituting a long zygal fissure (§ 307).

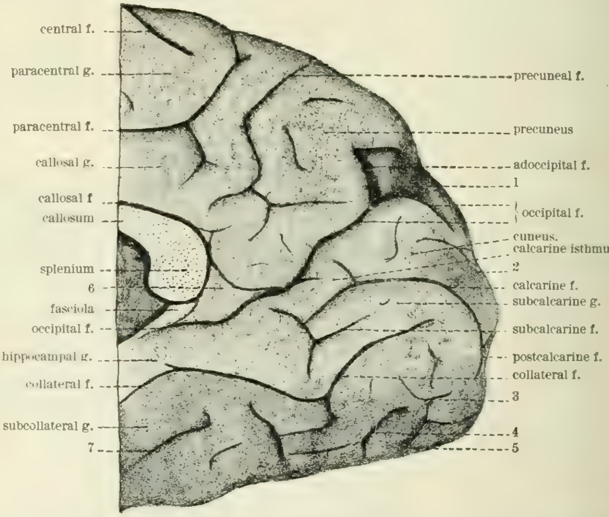

FIG. 754.—Caudal Half of the Mesal Surface of the Right Hemicerebrum of an Adult Female Paretic. No. 2,358 in the Museum of Cornell University. × 1.

C. The extension of the occipital fissure so as to represent what is usually the common stem of it and the calcarine.

D. The presence of a "spur" extending caudad from the occipital toward the calcarine upon the isthmus.

E. The appearance of trifurcation of the dorsal end of the occipital. The middle extension, however, is continuous with the fissure only superficially; the cephalic branch is apparently my adoccipital; the caudal, although doubtless the dorsal part of the occipital, presents an unusual curve and is invisible from the lateral aspect.

F. The extent of the precuneal fissure.

G. The considerable extension of the central upon the mesal aspect.

H. The presence of a subcalcarine fissure.

§ 247. Each of the forty or more fissures demands monographic treatment; but the limits of this article will permit the detailed consideration of only two, the central (§§ 269-303) and the paroccipital (§§ 309-325), as exemplifying different phases of fissural study.

§ 248. *Fig. 755 illustrates:* A. An early stage in the formation of the Sylvian fissure, the presylvian fissure being represented by a mere notch.

B. The incomplete separation of the calcar and the occipital eminence.

C. The size of the postcornu relatively to that of the entire hemicerebrum.

D. The corrugation constituting the collocated calcar and calcarine fissure.

E. The equally distinct collocation of the occipital fissure at this period with the adjoining colliculus, occipital eminence, sometimes called "bulb of the posterior cornu."

§ 249. *Collocation of Permanent Fissures with Cranial Sutures.*—In the adult the dorsal end of the occipital fissure has a notably constant position at the mesal angle of the lambdoidal suture, as seen in Fig. 670. With fetuses of between three and seven months this suture is decidedly caudad of the occipital fissure, but is distinctly collocated with the lambdoidal fissure (Fig. 750); this collocation does not persist after the seventh month, and it is not yet known whether the fissure disappears or changes its position. The approximate collocations of the central and other fissures with sutures are considered in the article *Brain, Surgery of the.*

§ 250. Fissures should be studied before gyres, because: 1, They are simpler, being represented by lines instead of planes; 2, they are more commonly entirely independent of other fissures; 3, they are comparable with the rivers of a region which are employed as boundaries of the subdivisions; 4, themselves structureless, they really represent the locations of a greater amount of cinerea than lines of equal width and extent on the gyres, and have thus a greater, presumptive, physiological significance, although there seems to be a difference of opinion as to the functions of the intrafissural cinerea.

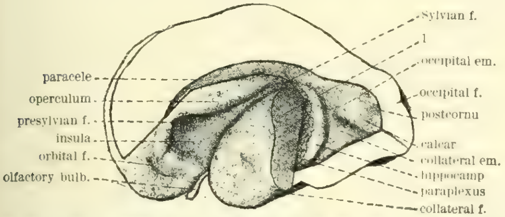

FIG. 755.—Left Hemicerebrum of a Fetus, Size and Age Unknown. Opened from the lateral aspect; 1,819. × 1. 1, Obliquely cut surface; the unshaded area represents a surface cut parallel with the meson. The line from *paraplexus* ends somewhat vaguely; it should reach the narrow zone between the hippocamp and the cut surface marked 1. See § 248.

§ 251. With children born at term the main fissures are always well defined, and in some cases there seems to be little difference between infant and adult cerebrums in respect to fissural complexity, although the insula is always less developed and less completely covered by the operculums (see Fig. 663). Such brains are often more readily obtained and removed than those of adults, and if well preserved and carefully handled may materially aid both teaching and research.

§ 252. For the elucidation of the intricacies of adult fissures, *fetal brains are much more serviceable than those of monkeys.* This, in contravention of the view and practice of Meynert, has been insisted upon by me (1886, *g*). Some of the peculiarities and complexities of the monkey brain are represented in Fig. 787.

§ 253. Adult cerebrums commonly present individual peculiarities which prevent their serving as types or standards. I have found such in every brain examined; not merely, for example, in that of the philosopher, Chauncey Wright (Figs. 768, 770, 788) but also in that of a mulatto; simple in several respects, it has peculiarities and complexities not as yet fully understood (see Figs. 762–766).

§ 254. *Fig. 756 illustrates:* A. In connection with Figs. 663 and 702, the perfection and beauty of form of the human brain at birth.

B. The relatively small size of the cerebellum at birth.

C. The distinctness and prominence of the pons.

D. The lateral extent of the pseudocele; at the genu (cephalic curvature) of the callosum it is 1 mm. deep, representing about one-half of its entire lateral extent.

E. The distinctness and depth of the principal fissures and the large number of minor ones.

F. The peculiar ventral curve of the caudal half of the calcarine fissure, and the concomitant expansion of the cuneus.

G. The length of the fissure in the subcalcarine gyre.

H. The appearance of the cephalic stipe of the paroccipital fissure (18) upon the meson (see Figs. 774 and 775).

§ 255. The study of fissures upon actual brains is facilitated by reference to diagrams such as have been published by C. L. Dana, Eberstaller, Ecker, Jensen, Pansch, Schäfer (in "Quain"), and others. My present views are embodied in Figs. 757 and 758.

§ 256. *Comments upon the Fissural Diagrams* (Figs. 757 and 758).—A. They represent my views at this time, but are not identical with those previously published (1886, *g*, and first edition of the REFERENCE HANDBOOK), and are subject to further modifications with increasing knowledge of the facts. For example, the small fissures caudad of the occipital are but little understood, and the orbito-frontal of Giacomini may prove to be more nearly constant than now supposed.

B. An attempt has been made to indicate the relative depth and constancy of the fissures by lines of three degrees of width; this grouping, however, is provisional.

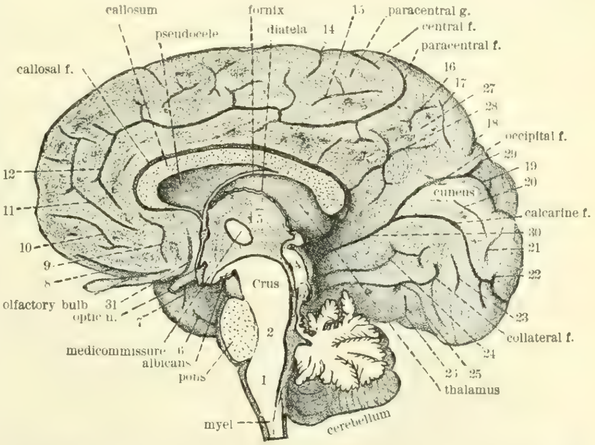

FIG. 756. Mesal Aspect of the Right Hemicerebrum of a Male Child, at Term; 478. × .84. Other aspects of the same specimen are shown in Figs. 663, 774, and 775. 1, Postoblongata; 2, preoblongata; 3, postgeminum; 4, pregeminum; 5, thalamus, its mesal surface, forming the lateral wall of the diacele; the dorsal, pial surface is designated by the line from the word *thalamus*; these are parts of one and the same organ, separated by the membranous diatela; but the triangular area dorso-cephalad of them marked *pseudocele* and apparently separated only by the narrow white area marked *fornix*, is the *hemiseptum*, part of the mesal surface of the cerebrum; 6, 9, 16, 17, 21, 23, 24, 25, 26, 31, unidentified fissures; 7, postrhinal; 8, olfactory; 10, 11, rostral fissures; 12, supercallosal fissure, continuous with the paracentral; 15, intraparacentral fissure; 14, inflected fissure; 18, cephalic stipe of paroccipital fissure; 19, a ventral branch of the occipital fissure; 20, 21, intracuneal fissures; 22, dorsal branch of the calcarine fissure; with the more caudal of the two ventral branches perhaps it represents the forked fissure sometimes called *postcalcarine*; 27, precuneus; 28, precuneal fissure; 29, dorsal end of the occipital fissure; 30, the common stem of the diverging occipital and calcarine.

Defects.—The specimen spread while hardening under its own weight, and is therefore wider and thinner than natural; this is, however, an advantage for the study of the fissures. The naturally considerable cranial flexure became still more marked as the brain rested upon the lateral aspect while photographing, and this, for convenience, is preserved in the drawing. The thalamus is unnaturally, though very instructively, uncovered by the callosum so that its caudal prominence, the pulvinar, is visible. The habena is not distinctly seen. The cerebellum is not represented accurately as to details, but is enlarged in Fig. 702. The hypophysis is lacking, and the aulic region is not shown in detail.

C. Each separate line represents what I now regard as a fissural integer so far as the human brain is concerned. The following are also regarded as integers, although continuous with others: occipital, calcarine, postcalcarine, postrhinal. The presylvian, subsylvian, and basisylvian are really branches or continuations of the Sylvian, but are separately named for convenience.

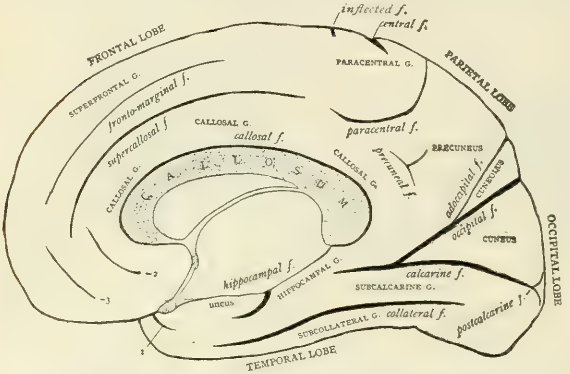

Fig. 757.—Diagram of the Fissures upon the Mesal Aspect. The outline and certain fissures are from the mulatto brain (322), which was hardened within the cranium.
1, Postrhinal (amygdaline) fissure; 2 and 3, rostral fissures.

D. The fissure lines are nearly straight and simple, excepting where branching is a practically constant feature, as, *e.g.*, with the paroccipital, paracentral, precuneal, and postcalcarine.

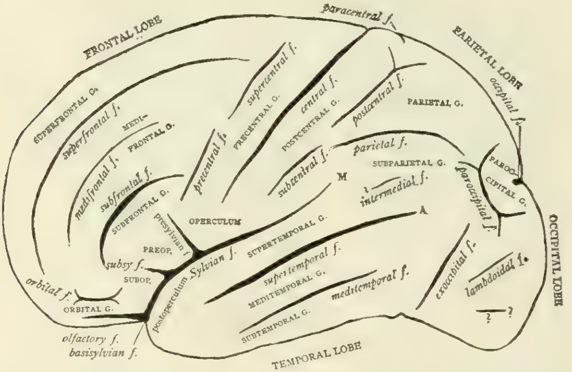

Fig. 758.—Diagram of the Fissures upon the Lateral Aspect. The outline and certain fissures are from the mulatto brain (322), which was hardened within the cranium. M, the "marginal" gyre; A, the "angular" gyre; Preop., the preoperculum; Subop., the suboperculum; Subsy. f., the subsylvian fissure. The interrogation points on the lateral aspect of the occipital lobe indicate my doubts as to the existence of certain fissures, or as to the names that should be applied to them if they do exist. The subtemporal fissure is not shown (see Fig. 765).

E. The connections are of two distinct kinds: primary, invariable, and inevitable from the mode of formation of the parts; secondary, and more or less common, but not necessary.

F. *Invariable* and apparently inevitable fissural connections are (1) of the Sylvian with the basisylvian, presylvian, and subsylvian, all which might be regarded as its continuations or branches; (2) of the callosal with the hippocampal.

G. *Usual* connections are of the occipital with the calcarine, and of the supercallosal with the paracentral, but there are occasional exceptions.

H. *Common* connections are of the superfrontal and supercentral; the precentral and subfrontal; the precentral and supercentral; the postcentral and subcentral and parietal; the parietal and paroccipital.

I. *Occasional* connections are of the precentral with the Sylvian, and of the central with the Sylvian over the margin of the operculum; in these cases, so far as known to me, the junction is seldom very deep.

§ 257. From the deservedly popular fissural diagrams of Ecker, the publication of which has so materially advanced the general knowledge of the subject, these differ mainly in the following respects:

A. The omission of branches and contortions.

B. The inclusion of the callosal, inflected, adoccipital, postrhinal, postcalcarine, medifrontal, precuneal, and postcentral fissures.

C. The disjunction of the supercallosal from the paracentral; of the precentral from the subfrontal and supercentral; of the postcentral from the subcentral; and of the subcentral from the parietal.

D. The recognition of the adoccipital fissure and the cuneolus.

E. The introduction of the exoccipital as probably representing the true "ape-fissure" of Wernicke.

F. The combination of the "transverse occipital" of Ecker with the caudal portion of his "interparietal" as a distinct fissural integer, the paroccipital.

G. The adoption from various writers of what seem to be the best fissural names of a single word each—*e.g.*, from Huxley, *collateral;* from Owen, *callosal, hippocampal, medifrontal, subfron-*

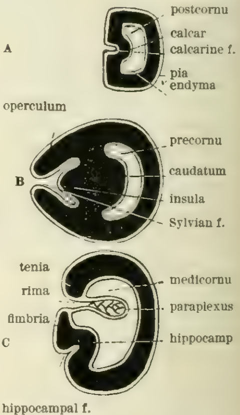

Fig. 759.—Schematic Transections of the Three Paracelian Cornua in the Order of their Complexity. See § 259.

tal, supercallosal ; from Wernicke, *fronto marginal ;* from Jensen, *intermedial ;* from Pansch, *occipital* and *parietal ;* from Schwalbe, *precentral* and *postcentral ;* from Meynert, *preoccipital ;* from Lussana and Lemoigne, *inflected* (Ital., *inflesso*).

H. The substitution of several mononyms for polyonyms, viz.: of *presylvian* for *ascending branch of the Sylvian ; subsylvian* for *anterior branch ; basisylvian* for the part ventrad of the presylvian; and the restriction of *Sylvian* to the "posterior branch."

I. The replacement of *lingual lobule* and *fusiform lobule* (not at all easy to apply correctly), by *subcalcarine gyre* and *subcollateral gyre,* names at once associated with the fissures which respectively constitute the dorsal boundaries.

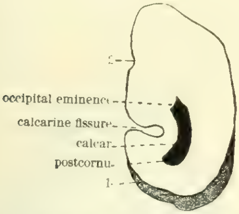

FIG. 760.—Transection of the Left Occipital Lobe of a Fetus, Size and Age Unknown ; 2,278. × 1.5. This figure is almost diagrammatic in its simplicity ; it shows very clearly the relation of the calcarine fissure to the calcar as represented in Fig. 759, A.

J. The use of one and the same word, *fissure,* for all the cerebral depressions excepting the two foveas.

K. The use of one and the same word, *gyre,* for all subdivisions of the lobes, excepting the cuneus and precuneus, already well distinguished by mononyms, and the cuneolus.

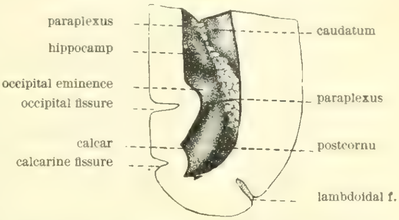

FIG. 761.—The Caudal Part of the Right Hemicerebrum of a Fetus, Measuring 14 cm. from Nates to Bregma, and Estimated at Four Months ; 1,816. × 1.5. (See § 261.)

Preparation.—This is part of the specimen shown in Fig. 727, where the mode of preparation is described ; the postcornu was exposed by removing the paracelian roof along the lines in that figure. The plexus was partly cut away, although not so represented in this figure.

§ 258. *Total and Partial Fissures.*—Of the permanent fissures most affect merely the cortex and the adjacent alba and are therefore sometimes called *partial* fissures; the central, for example, though constant and deep, is only a partial fissure. But others represent corrugations of the entire parietes, so that the ectal depression, fissure, is opposite and obviously correlated with, an ental elevation or colliculus; the fissures commonly enume-

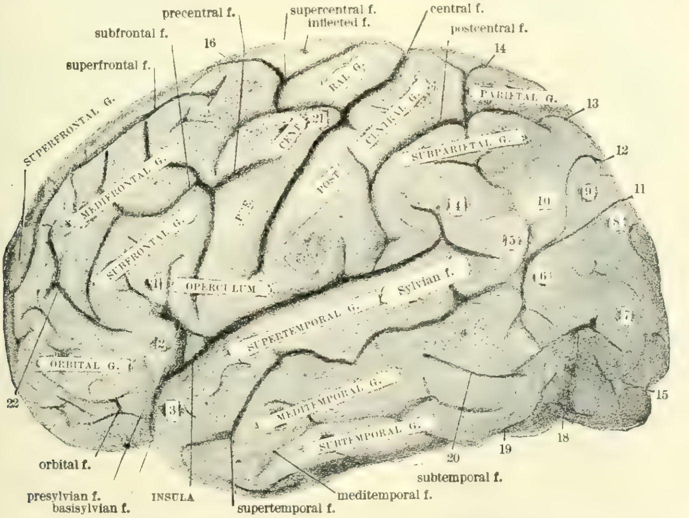

FIG. 762.—Lateral Aspect of the Left Hemicerebrum of a Mulatto ; 322. × .8. 1, Cephalic part of the operculum demarcated from the rest by a fissure that does not extend through its entire thickness ; 2, preoperculum ; 3, postoperculum ; the subsylvian fissure is probably represented by a short indentation, visible only when the postoperculum (3) is removed ; 4, what is commonly called the "supramarginal gyre" ; 5, may represent part of what is called the "angular gyre" ; 6, a supergyre overlapping the concealed, caudal part of the angular ; 7, unidentified occipital gyre ; 8, 9, portions of the unidentified supergyre that overlaps the lateral part of the paroccipital gyre ; 10, gyre at the caudal (apparently dorsal) side of the dorsal, deflected end of the supertemporal fissure ; 11, opposite the dorsal end of the occipital fissure (this is, however, invisible, and the straight fissure that extends laterad from 11 between 8 and 9, and curves ventrad at 6, may possibly be the exoccipital or Wernicke's fissure, one of the so-called "ape-fissures" ; it has apparent, though not real, connections with the occipital and supertemporal fissures) ; 12, curved fissure in the same supergyre, superficially connected with the supertemporal ; 13, cephalic stipe of the paroccipital fissure ; 14, dorsal fork of the postcentral fissure ; the subcentral is not indicated by a separate number and is continuous with the postcentral ; 15, caudal extremity of the calcarine fissure, really simple and independent ; 16, cephalic radius of the triradiate supercentral fissure (see Fig. 765) ; 18, 19, 20, unidentified occipito-temporal fissures ; 21, just ventrad of the strait between the central and supercentral fissures (see Fig. 764) ; 22, the most cephalic of three distinct fissures crossing the medifrontal gyre.

ated as total are the hippocampal (Fig. 755), calcarine (Fig. 760), and collateral (Fig. 755); the Sylvian may possibly be correlated with the caudatum (Fig. 716); the callosal and occipital are total fissures in the fetus (Figs. 734 and 761), and the ental correlative of the latter is sometimes recognizable in the adult (Fig. 744).

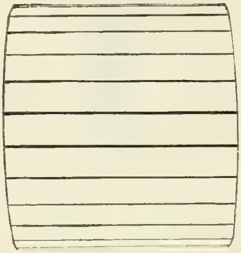

FIG. 763.—Diagram Illustrating the Effect of the Convexity of the Cerebral Surfaces upon the Apparent Width of the Gyres. Upon a cylinder were drawn parallel lines at the uniform distance of 1 cm.; one side of the cylinder was then photographed, and the figure is a reproduction of the photograph, reduced one-half. The reduction of the intervals according to the distance of the lines from the part nearest the eye illustrates the fact, not always distinctly recognized, that the fissures near the periphery of a cerebral convexity always appear to be nearer together than they really are; the intervening gyres consequently appear of less than their actual width; see, for example, the superfrontal gyre in Figs. 762 and 764.

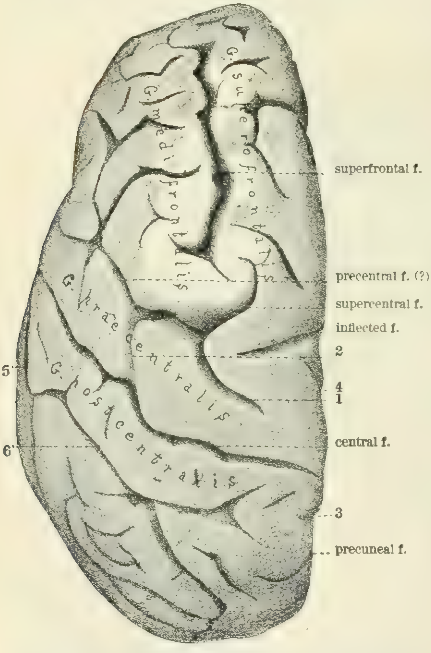

FIG. 764.—Dorso-Cephalic Aspect of the Left Hemicerebrum of a Mulatto; 322. × .8. 1, Caudal radius of the triradiate supercentral fissure; 2, strait between the central and supercentral fissures; 3, caudal end of paracentral fissure (see Fig. 766); 4, cephalic end of the same (?); 5, Sylvian fissure; 6, postcentral fissure. See § 264.

§ 259. *Fig. 759 illustrates:* A. The mesal wall of the postcornu presents a ridge, the calcar, and the mesal surface of the occipital lobe a furrow, the calcarine fissure; as seen in Figs. 760 and 761, the ectal depression and the ental elevation are obviously correlated.

B. The precornu presents an ental elevation, the caudatum, and a depression nearly opposite, the Sylvian fissure. But the correlation of the two is not quite clear and the conditions are complicated by the formation of the intrafissural (or intergyral) elevation called *insula.*

C. Here, as in the postcornu, there is no doubt respecting the correlation of the ental elevation or colliculus, the hippocamp, and the ectal furrow, the hippocampal fissure; in addition, the proper nervous parietes are abrogated along a line, the rima, and the paraplexus is formed by the intrusion of the pial process covered by the endyma; the margins of the rima are specialized and become the fimbria and tenia; on the figure the tenia is not indicated as separate from the caudatum (Fig. 730).

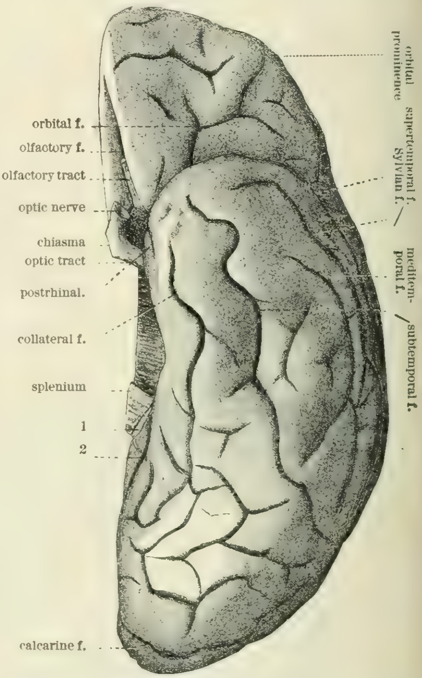

FIG. 765.—Ventral Aspect of the Left Hemicerebrum of an Adult Male Mulatto; 322. × .8. 1, Ridge ventrad of the splenium, representing, perhaps, one of the gyres described by A. Retzius, British Association Proceedings, 1885; 2, stem of the occipital and calcarine fissures. See § 265.

Preparation.—See Fig. 757. The olfactory bulb has been removed.

§ 260. *Classification of the Permanent Fissures.*—The following grouping of the fissures is approximately natural and has been found convenient by me; at the best, however, any such arrangements are provisional:*

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* Whatever may be desirable in theory, or eventually practicable, at present nothing seems to be gained by attempting to classify cerebral depressions as fissures and sulci, and in this article all are designated as *fissures*.

A. Total fissures, representing a corrugation of the entire paracelian parietes; *e.g.*, calcarine.

B. Partial fissures with some structural correlative; *e.g.*, olfactory.

C. Partial fissures, nearly or quite constant, and demarcating recognized gyres; *e.g.*, subfrontal.

D. Inconstant, intragyral fissures; *e.g.*, medifrontal.

§ 261. *Fig. 761,* in addition to A and B, specified under Fig. 727, *illustrates:* A. The contiguity of the two margins of the rima, excepting for the intruded paraplexus.

B. The concomitant, absolute exclusion of the thalamus from the paracelian floor.

C. The depth and peculiar form of the lambdoidal fissure (Fig. 750).

§ 262. *Fig. 762 illustrates:* A. The form of this adult, mulatto, left hemicerebrum, unaltered save from alcoholic shrinkage.

B. The general aspect of the gyres, comparable with the appearance in the cerebrum of the philosopher, Chauncey Wright (Fig. 788).

C. A simple, almost typical condition of certain fissures, *e.g.*, central and Sylvian, in a large part of their course, combined with great and unusual peculiarities of the same or other fissures.

D. The visibility of the insula (see Figs. 767 and 788).

E. The presence of a vertical branch of the presylvian fissure, which, however, does not extend through the thickness of the operculum.

F. The union of the subfrontal with the precentral and with two of the fissures crossing the medifrontal gyre.

G. The apparent narrowness of the superfrontal gyre, which nevertheless, as seen from the dorsal aspect, is of considerable width; in fact the narrowest portion of the superfrontal is just as wide as is the subfrontal measured in line with the stem of the presylvian fissure; this is a forcible exemplification of what is explained under Figs. 763 and 764.

H. The great length of the supertemporal fissure, and its apparent dorsal branching in four directions; its true and deep continuation is cephalad between 5 and 10.

I. The continuation of the calcarine fissure around the margin of the hemicerebrum so as to appear upon the caudo-lateral aspect as an undivided end (15); the calcarine is believed to be continuous commonly with a bifurcated postcalcarine, and the condition in this brain seems to be unusual; see also Fig. 785.

J. The superficial connection of the central and precentral fissures.

K. The partial appearance of the subtemporal fissure on the lateral aspect; see, however, Fig. 765.

L. The forking of the Sylvian into an episylvian fissure, near 4, and a hyposylvian near 5.

§ 263. The apparent width of gyres upon convex surfaces of the cerebrum is affected by the point of view. Compare, *e.g.*, the superfrontal gyre of the mulatto as shown in Figs. 762 and 764. The conditions are schematically illustrated in Fig. 763.

§ 264. *Fig. 764 illustrates:* A. The length and independence of the superfrontal fissure, and its close parallelism with the hemicerebral margin.

B. The width of the supercentral gyre when viewed directly as compared with the oblique view shown in Fig. 762 (see § 262, G).

C. The triradiate form of the supercentral and its relation to the inflected.

D. The continuity of the supercentral with the precentral and central; in each case, however, there is a vadum or shallow.

§ 265. *Fig. 765 illustrates:* A. The presence of a distinct though rounded orbital prominence between the frontal and the lateral portions of the outlines, but the absence of any such boundary between the lateral outline and the occipital.

B. The narrowness of the olfactory gyre, between the olfactory fissure and the mesal margin of the frontal lobe.

C. The distinctly zygal form of the orbital fissure.

D. The length and distinctness of the subtemporal fissure.

E. The extension of the calcarine fissure upon the occipital end of the hemicerebrum.

F. The presence of a fissure (orbito-frontal?) on the orbital surface cephalad of the orbital fissure.

§ 266. LIST OF PARTIAL FISSURES, CONSTANT OR NEARLY SO, AND DEMARCATING GYRES.

Fissures.	Aspect.	Gyres separated by them.
1. Basisylvian....	Ventral	Orbital. Temporal.
2. Central	Lateral	Precentral. Postcentral.
3. Circuminsular .	Lateral	Insular. Adjoining.
4. Inflected.......	Lateral	Superfrontal. Precentral.
5. Insular........	Lateral	Insular.
6. Olfactory......	Ventral	Orbital. G. rectus.
7. Orbital........	Ventral	Subfrontal. Orbital.
8. Orbito-frontal.	Lateral	Superfrontal. Orbital.
9. Paracentral...	Mesal	Paracentral. Precuneus, etc.
10. Parietal	Lateral	Parietal. Subparietal.
11. Paroccipital...	Lateral	Paroccipital. Subparietal.
12. Postcentral....	Lateral	Postcentral. Parietal.
13. Postrhinal.....	Mesal	Uncus Temporal
14. Precentral.....	Lateral	Precentral. Medifrontal.
15. Presylvian	Lateral	Operculum. Preoperculum.
16. Subcentral	Lateral	Postcentral. Parietal.
17. Subfrontal	Lateral	Subfrontal. Medifrontal.
18. Subsylvian...	Lateral	Preoperculum. Suboperculum.
19. Supercallosal..	Mesal	Callosal. Fronto-marginal.
20. Supercentral..	Lateral	Precentral. Super- and medifrontal.
21. Superfrontal...	Lateral	Medifrontal. Superfrontal.
22. Supertemporal.	Lateral	Supertemporal. Meditemporal.
23. Transinsular...	Lateral	Preinsula. Postinsula.

§ 267.—LIST OF INCONSTANT FISSURES, WITH THE GYRES IN WHICH THEY OCCUR.

Fissures.	Gyres.
1. Adoccipital	Precuneus.
2. Episylvian	Subparietal.
3. Exoccipital	Occipital (?).
4. Fronto-marginal	Fronto-marginal.
5. Hyposylvian.............	Supertemporal.
6. Intermedial	Subparietal.
7. Intraparacentral	Paracentral.
8. Medifrontal..............	Medifrontal.
9. Postcalcarine	Occipital (?).
10. Postcuneal...............	Occipital (?).
11. Postoccipital fovea	Occipital (?).
12. Postparoccipital	Paroccipital.
13. Precuneal	Precuneus.

14. Preoccipital fovea	Subtemporal.
15. Preparoccipital	Paroccipital.
16. Rostral	Callosal.
17. Suboccipital	Occipital (?).
18. Subtemporal	Medi- and subtemporal.
19. Transtemporal	Meditemporal.

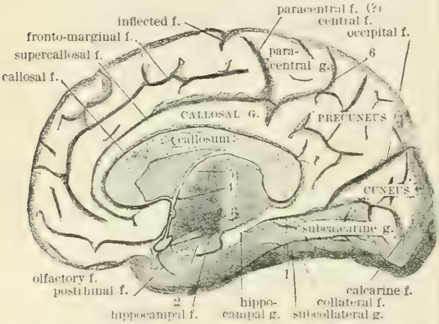

FIG. 766.—Mesal Aspect of the Left (Reversed So as to Appear the Right) Hemicerebrum of an Adult Male Mulatto; 322. × .5. 1, The common stem of the occipital and calcarine; 2, uncus; 3, optic tract, divided obliquely; 4, fornix; 5, retreating ventral surface of the fornix; 6, paracentral fissure. There can be no doubt that 6 is the caudal or main portion of the paracentral, but the cephalic portion so named is thought by E. A. Spitzka to represent the intraparacentral, the true cephalic limb being absent. Mr. Spitzka concludes (1900) that the inflected, like the central, typically indents the margin of the paracentral gyre. Unfortunately, at this time, I cannot determine the point by re-examination of the specimen; but the need of doing so exemplifies the remark in § 253.

Preparation.—See Fig. 757.

Defects.—Most of the fissure lines are too faint; the emargination of the ventral outline just cephalad of the optic nerve is too decided.

§ 268. *Fig. 766 illustrates:* A. The existence and unusual extent of the fronto-marginal fissure.

B. The complexity of the precuneal fissure.

C. The length of the collateral fissure.

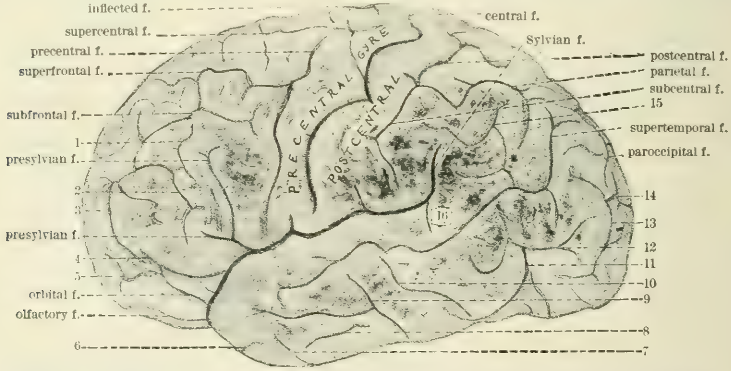

FIG. 767.—Lateral Aspect of the Left Hemicerebrum of an Adult Swedish Carpenter, Presenting an Unusual Degree of Fissuration; 318. × .6—. *Preparation.*—The hemicerebrum was hardened resting upon the mesal surface, and apparently with little change in form. The right was likewise numerously fissured. Of the unidentified fissures the only ones that seem to call for comment here are 9 and 10, which are transtemporal fissures, and 16, a well-marked hyposylvian. See § 275.

D. The distinctness of the postrhinal fissure.

E. An apparent peculiarity of the paracentral fissure as stated briefly in the description; the subject is discussed by E. A. Spitzka, 1900.

§ 269. *Pre-Eminent Importance of the Central Fissure.*—Taking all things into account, the central fissure demands first and fullest consideration; there is, indeed, no fact concerning it that is not worth recording or that may not prove significant morphologically or practically valuable. The order in which the following topics are presented is far from perfect, but it may serve to indicate the many-sidedness of these cerebral features. To save space the pronoun *it* will commonly designate the central fissure.*

§ 270. *The Name.*—It has been called, to use the Latin forms, *fissura, scissura,* and *sulcus,* with the qualifying adjectives *centralis, Rolandica,* and *postero-parietalis,* all these having, of course, appropriate equivalents in the various modern languages. My doubts as to the utility of discriminating, at present, between fissures and sulci have been expressed in § 260, *note.* My reasons for preferring *central* to *Rolandic* have been stated upon several occasions since 1882; but as the former name has now been adopted by the Association of American Anatomists and the Anatomische Gesellschaft it will probably supersede the latter with anatomists of other nations.

§ 271. *General Location and Direction.*—On the dorsolateral aspect of the cerebrum, at about the middle of its length; from a point at or near the dorsi-mesal margin, it extends latero-cephalad at an angle of about 70 degrees with the meson, or about 140 degrees with its opposite.

§ 272. *Dimensions.*—Among adult hemicerebrums in the museum of Cornell University the length of the fissure, measured in a straight line between the two ends, varies from 8 to 10.5 cm., the usual length being about 9.5 cm., or about one-fourth of the entire circumference of a cerebrum as measured in a dorso-ventral plane intersecting the fissure at about the middle of its length. If measured along the sinuosities, as if the fissure were straightened out, the length may be one-seventh greater than if measured across the curves. The greatest depth varies from 10 to 15 mm.

§ 273. *Relation to Ental Elevations.*—There is no evidence of any special collocation between it and any ental elevation, in man or any other mammal; hence, though so deep, it is not a total but a partial fissure (§ 258, A).

§ 274. *Constancy.*—The only case of absence of the central fissure known to me is that described by Sir William Turner (*Jour. Anat. and Physiol.*, xxv., 327–348). The subject was an epileptic, twenty-six years old, and the entire (alcoholic) brain weighed 1,107 gm. (39¾ ounces);

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* The central fissure is quite fully discussed by Cunningham (1892, chap. iii.).

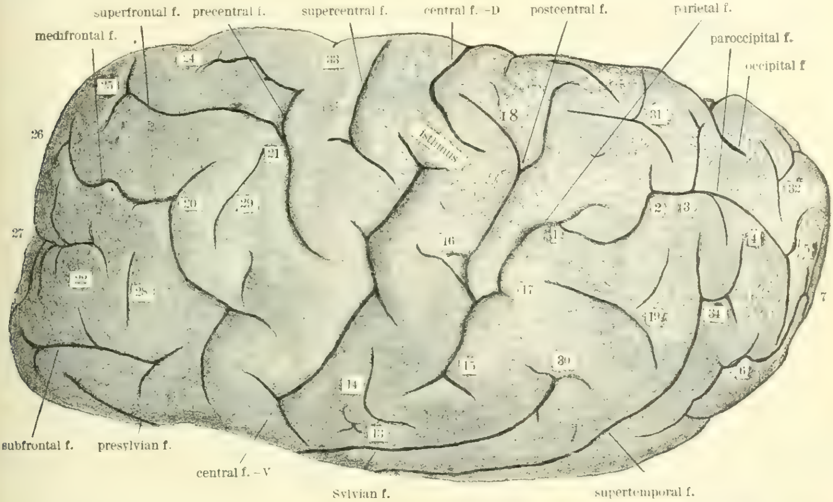

FIG. 768. The Left Hemicerebrum of a Philosopher (Chauncey Wright), from the Dorso-Lateral Aspect. × .9.

Preparation. See Fig. 788. The figure is based upon a photograph taken as nearly as possible at an angle of 45° with the meson, so as to present the dorso-lateral aspect. The line connecting the superfrontal and medifrontal fissures was made inadvertently.

The numerals 1 to 22 are at the same points as in Fig. 788; on that figure 23 designated the central isthmus, which here has the word printed upon it; 33 is just at the end of the short inflected fissure.

the left hemicerebrum 530 gm., the right 437. The left fissures are stated to have had a normal development and arrangement, but on the right the Sylvian fissure was wide open so as to expose the insula largely; *the central fissure was wholly absent*, together with the precentral and postcentral; the lateral surface presented three arched fissures, demarcating four arched gyres about the Sylvian fissure, a condition analogous to that in the dog and many other carnivora. The interest and importance attaching to this case would have warranted a larger number of better figures, and a representation of the left hemicerebrum.

§ 275. *Fig. 767 illustrates:* A. The unusual number of minor fissures, especially of the slight depressions which I have called *fossulæ*.

B. The three cephalic curves of the central fissure, and their decided character.

C. The extent of the supertemporal fissure.

D. The continuity of the postcentral, parietal, and paroccipital fissures.

E. The length of the dorsal branch of the presylvian.

F. The two dorsal branches of the Sylvian, and the distinct hyposylvian branch (16).

G. The crossing of the temporal lobe ventrad of the supertemporal fissure by two transtemporal fissures.

H. The non-union of the subfrontal with the precentral; this last is not named but is the ventral continuation of the supercentral, beginning about opposite the subfrontal.

I. The continuity of the postcentral, subcentral, parietal, and paroccipital, constituting what has been called the "intraparietal complex"; § 306.

§ 276. *Topographical Importance.*—This is well indicated in the following vigorous declarations of Wagner and Ecker: "*Man muss sie immer zuerst aufsuchen, um sich von da in dem scheinbaren Chaos der Hirnwindungen. . . .*" "*Bildet sie die den sichersten Ausgangspunkt fur die Aufsuchung der Windungen. . . .*"

§ 277. *Form, or Course in Detail.*—According to Broca it normally presents two cephalic convexities with an intermediate caudal convexity. In most adults it is certainly more or less serpentine or tortuous, and the regular curves are sometimes distinct; but three cephalic convexities have been observed in sufficient number to show the need of careful observation and tabulation.

§ 278. *Branches.*—Offshoots from the central are usually rather short and straight, starting at the summits of the curves; but in the brain presenting the most decided curvatures (Fig. 767) there is scarcely any branching.

§ 279. *Fig. 768 illustrates:* A. The unfamiliar appearance of a hemicerebrum when viewed from this oblique aspect.

B. The distinctness of the angles between the cephalic and the dorsal and ventral outlines; this was commented upon by the first describer of this brain, Prof. Thomas Dwight, and appears in Fig. 788, though less markedly.

C. The completeness and width of the isthmus between the dorsal and ventral portions of the central fissure; in Fig. 788 this is marked 23, but is so much foreshortened as to be hardly visible.

D. The simple, curved form of the dorsal part of the central fissure, with no bifurcation such as exists at both ends of the ventral portion.

E. The independence of the supercentral fissure.

F. The presence of a medifrontal fissure subdividing the large area between the subfrontal and superfrontal fissures.

G. The junction of the subcentral fissure with the parietal, and the continuity of the parietal with the paroccipital; whether this junction occurs at 1 or at 2 cannot be determined at present.

H. The great length of the supertemporal fissure and the complexity of its dorsal end.

I. The presence of a long and curved fissure, 6–7, on the lateral aspect of the occipital lobe.

J. The presence of an unusual crescentic fissure (14) ventrad of the subcentral (15).

§ 280. *Junctions.*—So far as I am aware, connections between the central and other fissures (excepting the intercerebral, § 236) are rare, and incomplete or shallow when they occur; *e.g.*, in Fig. 762, where the concealed vadum between the central branch and the supercentral nearly reaches the surface, and in Fig. 767, where there is also a nearly invisible vadum just at the apparent union of the supercentral with the central. The occasional confluence of the central with the Sylvian over the margin of the operculum is commonly shallow, but sometimes quite deep, as in the right hemicerebrum of James Burk, figured by Mills (*Journal of Nervous and Mental Disease*, vol. xiii., September, 1886). The depth of such straits should always be stated.

§ 281. *Bifurcation.*—Terminal division of the central fissure at either end is rare; among the few cases known to me the ventral end is bifurcated on the right in a supposed insane person (385) and the ventral on the left of Chauncey Wright (Fig. 768); the dorsal end is bifurcated on both sides in Professor Oliver (Fig. 664).

§ 282. *Relation to the Mesal Aspect.*—Cunningham found (1892, 162) that the fissure indented the dorsal margin so as to appear on the mesal aspect (as in Fig. 757) in sixty per cent. of the hemispheres examined. My own observations would make the proportion somewhat larger. For the final determination of the ratio there should be employed only adult specimens retaining their natural form.

§ 283. *Special Location.*—About midway between a line coinciding with the precentral and supercentral fissures cephalad, and a line coinciding with the postcentral and subcentral caudad.

§ 284. *How to Distinguish from Adjoining Fissures.**—When the precentral is separate from the supercentral, and the postcentral from the subcentral, the central is notably longer than either. When these two pairs of fissures unite, however, it is the middle of the group of three fissures at about the middle of the hemicerebrum having a general dorso-ventral direction. The following characters should be noted in case of doubt: its greater depth and length; its location relatively to the entire length of the cerebrum, and the angle it forms with the margin; its more complete independence; the usual absence of terminal forks; particularly its extension to or across the dorsal margin just cephalad of the paracentral, thus indenting the paracentral gyre (Fig. 769).

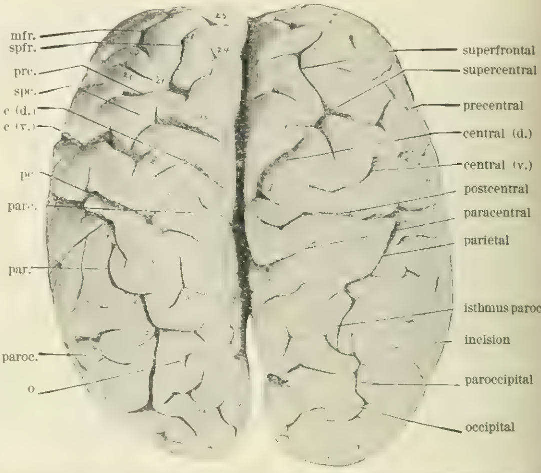

FIG. 770.—Dorsum of the Cerebrum of Chauncey Wright, a Philosophic Writer, Critic, and Mathematician (see description of Fig. 788). × .8. When photographed the cerebrum was inadvertently tilted a little to the left. I, Central isthmus on either side; the numbers correspond to those on Figs. 768, 779, and 788.

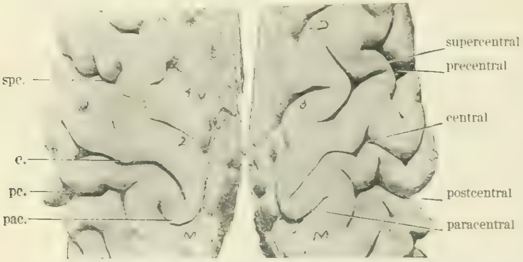

FIG. 769.—Right and Left Paracentral Regions of an Adult; 3,132. × .5. Each piece was cut from the dorso-mesal region of the hemicerebrum by an incision at about 45° with the meson; the pieces rest upon the oblique cut surfaces and the dorso-mesal margins correspond approximately to lines between the two Ds and the two Ms. 1, Dorsal outcrop of the cephalic end of the paracentral, which is also continuous with the supercallosal; 2, a crescentic fissure which, in the foreshortened position of the parts, appears to join the paracentral, but is really separated from it by a vadum barely below the surface; 3, a similar fissure on the right, separated by a complete isthmus from the paracentral, which latter has no dorsal outcrop, but is continuous with the supercallosal; in the light of E. A. Spitzka's observations 2 and 3 may be the inflected fissures.

§ 285. *Alleged Duplication.*—Calori and Giacomini have each described (1884) a brain which they interpreted as having two central fissures nearly parallel and separated by an "intercentral" gyre. The conditions in an educated suicide (3129) were similarly interpreted by me (1894, *a*); but a later comparison with a larger number of brains leads me to conclude rather (1900, *a*) that the supposed second or caudal central is really an unusually long resultant of the union of the postcentral and subcentral, caudad of which is the parietal. The bifurcated dorsal end of the postcentral has the usual relation with the paracentral as it crosses the meson (see Fig. 769).*

§ 286. *Fig. 769 illustrates:* A. The more usual relation of the central fissure to the dorsal margin, crossing it so as to appear on the mesal aspect.

B. The constant relation of the central

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* The macroscopic methods here enumerated might require confirmation from the histology of the region in question, as indicated in the discussion of my paper, 1900, *a*, by Donaldson, Spiller, and Mayer (Jour. Nerv. and Mental Disease, October, 1900, 540).

* After the above paragraph was in type the kindness of Dr. D. S. Lamb enabled me to obtain a transcript of the "Nota preventiva" of C. Leggiardi-Laura (Archiv di Psich. Sci. Penol. ed Antrop. Crimin., Torino, 1899, p. 421), "Duplicita della scissura di Rolando nei criminali." It is there claimed that among thirty-seven female brains central reduplication occurred once, on the left, and among thirty males, twice on the left, once on the right, and once on both sides. In the absence of figures, especially photographs, and detailed descriptions, I must refer these to the same category as my own; see also the remark of Dr. C. K. Mills upon my paper (1900, *a*) in Jour. Nerv. and Mental Disease, October, 1900, pp. 537–541, and my later note on the subject, 1900, *x*.

fissure to the paracentral, the former directed at the concavity of the latter.

C. The usual relations of the paracentral and postcentral fissures, the former directed at the reentrant angle formed by the bifurcation of the latter.

D. The not unusual bifurcation of the supercentral (upper precentral) fissures.

E. The asymmetry of the paracentral in respect to a dorsal outcrop of the cephalic end.

F. The danger of depending upon appearances in respect to the independent fissures 2 and 3.

§ 287. *Interruption.*—As shown in Figs. 770 and 771, the central fissure is completely interrupted on both sides of the brain of Chauncey Wright, the isthmus* being fully on a level with the adjacent gyres. The brain of Dr. Fuchs, figured by Wagner, exhibited a like peculiarity, and the complete interruption has now been recorded for perhaps fifteen hemicerebrums, a very small proportion of the enormous number examined. The left central is completely interrupted in the educated suicide (3,129) referred to in § 285; but the right is continuous.

§ 288. *Fig. 770 illustrates:* A. The unusual squareness of the frontal outline.

B. The unusual length of the region caudad of the central fissures, and concomitantly that of the parietal fissure.

C. The width and simplicity of most of the gyres, especially as compared with those of Professor Oliver (Fig. 664).

D. The complete interruption of both central fissures by an isthmus, (Fig. 771).

E. The lack of symmetry of the central fissures in respect to (*a*) distance of the isthmus from the meson, (*b*) difference in form of the dorsal portions; (*c*) unlike dorsal terminations of the ventral portions.

F. The unusual depth of both paracentral fissures and their non-oppositeness.

G. The unusually caudal location of the right paracentral so as to embrace the dorsal end of the postcentral as if the latter were the central.

H. The asymmetric condition of many other fissures.

I. The unequal depths of the occipitals; the right extends barely beyond the rounded cerebral margin; the left is at least three times as deep; this fact has been ascertained since the publication of the diagram of the paroccipital region in the Proceedings of the Ass'n Amer. Anatomists, 1895.

J. The details of the paroccipital region are considered under Fig. 779. In certain respects this brain is unique and merits extended monographic treatment; but this also will be easier and more instructive when a normal standard has been more nearly obtained.†

§ 289. *Partial Interruption.* — Several writers have called attention to the not infrequent presence of a vadum or shallow in the depths of the central fissure, commonly nearer the dorsal end; among 1,087 hemicerebrums examined, Heschl found in 152 (about fourteen per cent.) an elevation (vadum) rising from one-sixth to five-sixths of the entire depth of the fissure, and suggests that the rare cases of complete interruption result from the greater development of this feature. In view of these observations the vadum should always be looked for.*

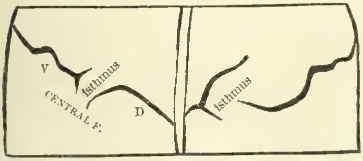

FIG. 771.—Central Region of the Dorsum of the Cerebrum of Chauncey Wright (Fig. 770), showing only the interrupted central fissures and the isthmuses; on the left the two portions of the fissure are designated by V and D respectively. × 5.

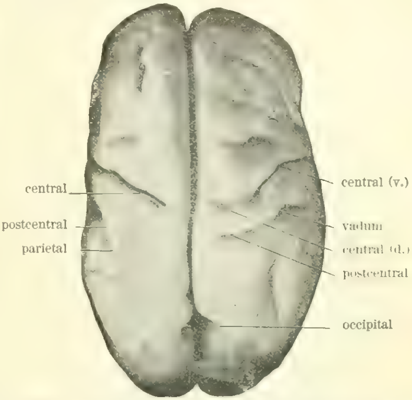

FIG. 772.—Dorsum of the Cerebrum of a Fetus Supposed to be Six Months Advanced; 2,972. × 1. One of twins, both males, stillborn.

§ 290. *Mode of Formation.*—In at least three specimens in the Cornell Museum, viz., 827 (Fig. 773), 2,278 (Fig. 752) and 2,972 (Fig. 772) there are evidences that the central begins in at least two portions, a dorsal and a ventral. Cunningham's views are summarized thus in 1897, *a*, 593:

"1. The typical mode of development is in two more or less distinct pieces. 2. Judging from the specimens in my possession this would likewise appear to be the more usual mode."† The cases of partial (by vadums) or total (by isthmuses) interruption in the adult may be regarded as retentions of the (usual or not infrequent) fetal condition.

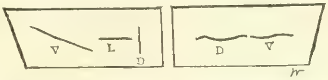

FIG. 773.—Diagrams of the Right and Left Central Fissure Regions of a Fetus, 56 cm. Long and Estimated at Twenty Weeks; 827. × 2.

§ 291. *Fig. 772 illustrates:* A. The unsymmetrical development of the central, postcentral, and parietal fissures.

B. The representation of the right central fissure by a longer ventral portion; a dorsal portion which is merely a dimple, but perfectly distinct; and an intervening vadum.

§ 292. *Fig. 773 illustrates:* A. The interrupted condition of both central fissures at their first formation.

B. The lack of symmetry; on the right are two parts, the right ventral (V) being 2 mm. deep at its middle and the dorsal (D) 2.5 mm.; on the left are three distinct divisions—the dorsal parallel with the meson, the lateral at right angles with it, and the ventral oblique.

§ 293. *Time of First Appearance.*—Nearly all writers state that the central fissure is formed about the end of the fifth month, the twentieth week. The following observations show that there is probably some variation in this respect, or—as is perhaps equally probable—that the length of the fetus varies considerably at the same stage of fissural development. In fetuses 827 and 1,817, respectively 56 and 65 cm. long, the fissure is vague or absent; in 1,820, 61 cm. long, it is distinct and deep; in 2,278, 67 cm. long, it is well developed, and several other lateral fissures are visible.

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* This term is equivalent to *pli de passage*, *annectent convolution*, and *bridging convolution*; the latter is misleading, for the interruption of a fissure has no analogy with a bridge, but rather with a dam, dike, or isthmus, absolute size being of no moment.

† The need of an improved standard for the study of fissures is clearly recognized by Mickle, 1895, opening paragraph.

* The morphological and zoological significance of vadums is forcibly stated by Cunningham (1897, *a*, 593): "A close study of the memoir of Retzius (1897) has left on my mind the impression that he somewhat understates their morphological value. With Eberstaller I hold that they constitute one of the great and distinctive characters of the human brain."

† The distinction between "*typical*" and "*usual*" in a case like this is not apparent.

§ 294. *Relative Order of Appearance.*—Excluding the transitory fissures (Fig. 748) and the lambdoidal (which may be transitory, Fig. 750), the central is apparently the first of the lateral fissures to be developed after the Sylvian (Fig. 751). But some of my preparations indicate that this order may not be invariable; in 2,081 the parietal and supertemporal are more advanced than the central; in 1,817 there is no trace of a central, although both superfrontals are distinct. Numerous and careful observations are needed on this point.

§ 295. *Form in the Fetus.*—When first distinctly formed, the fissure line is nearly straight, with a slight cephalic convexity (Fig. 751).

§ 296. *Proximate Cause.*—There is no evidence that it depends upon the pressure of a blood-vessel. The causation of fissures and of encephalic corrugations in general has been discussed by Jelgersma, Cunningham (1892), and A. J. Parker (1896), and briefly by Schäfer (1893, 162).

§ 297. *Relation to Primitive Fissures.*—There is no good reason for regarding either of the three radiating, presumably transitory, fissures shown in Fig. 746, as the direct precursor of the central.

§ 298. *Integrality.*—For the definition of *fissural integer* see § 305. The occasional complete interruption (§ 287), the not infrequent existence of a vadum (§ 289), and the mode of appearance in several cases (§ 290), suggest the possibility that the central consists really of two fissural integers, commonly connected, and comparable, perhaps, with the parietal and paroccipital (§ 306). For the present, however, it seems justifiable and certainly more convenient to regard the conditions above named as anomalous, and to treat the central as a single fissure.

§ 299. *Lateral Variation.*—Clevenger states that it is usually located farther caudad on the left side than on the right; its relations to motor areas would lead one to expect considerable lateral variation in position, direction, and shape.

§ 300. *Physiological and Surgical Relations.*—It is completely surrounded by important motor areas, and its exact relations to the cranium and surface of the scalp are of great pathological and surgical importance. these matters are considered in the articles *Brain, Surgery of the*, and *Brain: Functions of Cerebral Cortex.*

§ 301. *Psychological Relations.*—Clevenger has a suggestive paper (*Journal of Nervous and Mental Disease*, April, 1880) on the ratio between the location of this fissure and the intelligence of the individual or species; although unable to admit his identification with the cruciate fissure of Carnivora, or to accept all his conclusions, I regard the determination of the relative bulk of the precentral (frontal) region of the cerebrum and the postcentral (occipito-parieto-temporal) region as of great importance in connection with the comparison between individuals and species in respect to intellectual power and voluntary inhibition or self-control.

§ 302. *Condition in Other Primates.*—In the apes and in all the ordinary monkeys the fissure is readily recognized: *e.g.*, in the *Macacus*, Fig. 787.

§ 303. *Carnivoral Representative.*—By various authors it has been homologized with the following fissures of the cat and dog: superorbital, ansata, coronal, and cruciate. Notwithstanding the similar relations of the central and cruciate fissures to motor areas, the question of their homology (morphological identity) must be held as yet undetermined. A clue may be furnished by the observations of P. A. Fish (1899, 37) as to the collocation, in the seal (*Phoca*), of what seems to be the calcar with the ventral portion of the splenial fissure.

§ 304. *Fig. 774 illustrates:* A. The form of a perfect and typical paroccipital fissure, very symmetrical, and completely independent of the parietal, although its cephalic ramus and what seems to be an extension of the parietal overlap and approach very closely.

B. The peculiar appearance of the entire hemicerebrum and of the central fissure from this point of view. Other points are commented upon under Fig. 775.

§ 305. *Fissural Integer.*—This term was proposed by me (1886, *e*) to designate a fissure which is independent in some species or individuals, and deepest at or about the middle of its length, corresponding nearly with the place of its first appearance. Any marked and frequent shallowing of a supposed fissural integer is reason for questioning its integrality, and for seeking, in other individuals and in allied species, evidence that it really consists of two.

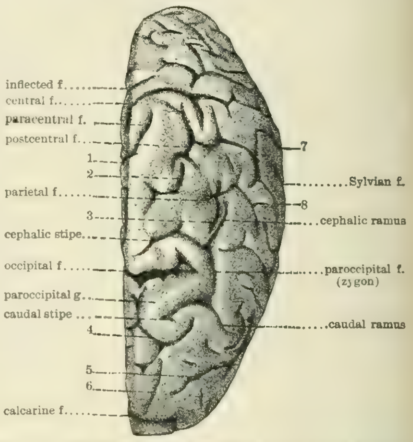

Fig. 774.—Dorso-Caudal Aspect of the Right Hemicerebrum of a Child at Birth; 478. × 1. This figure was published in the *Journal of Nervous and Mental Disease*, June, 1886. Other aspects of the same brain are shown in Figs. 663, 756, and 775.

§ 306 *The "intraparietal* fissure"* of Turner probably represents two fissural integers, the parietal and the paroccipital, because (1) in nearly half the cases examined by me there are two fissures separated by an isthmus of greater or less width; (2) when the two are continuous there is often a vadum at the point corresponding to the isthmus; (3) each of the two portions, whether separate or continuous, is usually deepest at or near its middle; (4) at their first appearance in the fetus they are always completely independent.

§ 307. *The typical paroccipital fissure* consists of (*a*) the zygon or bar, the first part to be formed; (*b*) cephalic and caudal stipes continuing the curve of the zygon about the dorsal outcrop of the occipital; (*c*) cephalic and caudal rami, imparting to each end the characteristic form seen in Fig. 774. The paroccipital is a typical zygal fissure.

§ 308. *Fig. 775 illustrates,* in addition to points seen equally well in Figs. 756, 663, and 775), the greater depth of the paroccipital zygon at the middle of its length, a fact hardly compatible with the supposition that it is only a caudal extension of the parietal, or that the caudal stipe and ramus constitute an independent fissure, the "transverse occipital" of Ecker.

§ 309. *What Is the So-Called "Transverse Occipital Fissure"?*—Most writers seem disposed to adopt the view of Ecker that the caudal stipe and ramus of the paroccipital represent a "sulcus occipitalis transversus" which unites with the longitudinal bar or zygon. None of the specimens examined by me seems to confirm this interpretation, and I am compelled to regard the very interesting condition shown by Cunningham (1892, Fig. 51) as simply anomalous. Much, however, remains to be done in this region.

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* Often, but incorrectly, written interparietal.

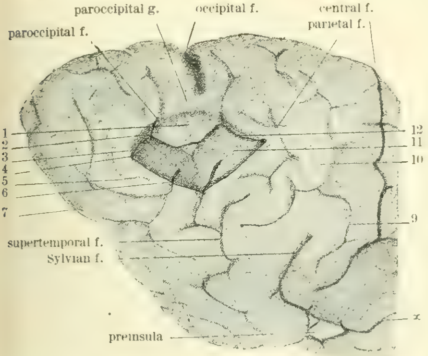


FIG. 775.—Dorso-Caudo-Lateral Aspect of the Right Hemicerebrum of a Child at Birth, Partly Dissected; 478. × 1. See the lateral and dorsal aspects (Figs. 663 and 774). 1, Lateral surface of the zygal part of the paroccipital gyre; this is, of course, pial, but the point of the V-shaped incision reaches a slightly lower level than the bottom of the fissure, occasioning the triangular cut area at the bottom; 2, line representing the junction of the zygon with its caudal stipe; 3, ectal line of the caudal ramus; 4, ental line of the same; 5, should have crossed the cut surface to the outcrop of the fissure marked 7 in Fig. 663; 6, the exoccipital fissure (?); 7, unidentified fissure; 8, presylvian fissure; 9, postcentral fissure; 10, gyre between the postcentral and the parietal fissures; 11, cephalic slope of the cut surface; 12, cephalic ramus.

Preparation.—By reference to the lateral aspect, Fig. 663, the paroccipital fissure will be seen to be indicated by the name itself, connected with the middle of the zygon. For the present figure a wedge-shaped piece was removed by two incisions, starting respectively at the tip of the rami and meeting at an obtuse angle at the exoccipital. The removal of this piece exposed the lateral aspect of the paroccipital gyre and of the gyres adjoining it cephalad and caudad; also the depth of the zygon and the two rami.

§ 310. *Fig. 776 illustrates:* A. The degree of fissuration at this period.

B. The early condition of the paroccipital fissure as a upsiloid (U-shaped), depressed line with lateral branches, rami.

C. The independence of the paroccipital fissures at this period.

D. The absence of any fissure closely resembling the "transverse occipital."

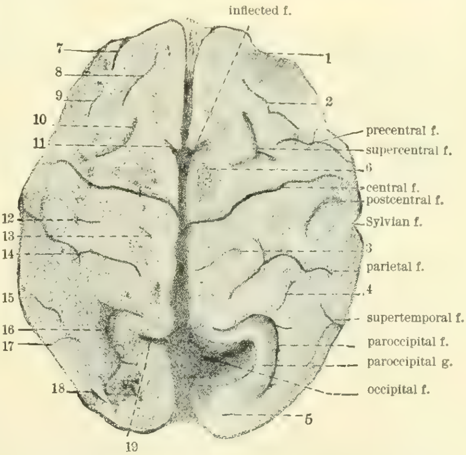


FIG. 776.—Dorso-Caudal Aspect of the Brain of a Fetus Measuring 41 cm. from Heel to Bregma, and Estimated at Eight Months; 734. × 1. 11, Left inflected fissure; 12, 13, separate portions of the left postcentral; 14, left parietal (?); 16, left paroccipital; 17, left supertemporal; 19, left occipital fissure. The remaining numbers indicate fissures of doubtful identity.

Preparation.—The arteries were injected with starch mixture; extravasation took place at several points, especially the two following: (1) into the dorsal part of the right occipital fissure, converting it into a kind of fossa, at the bottom of which is seen the unaffected part of the fissure; (2) into the left paroccipital fissure, separating its walls to some extent. The essential relations of parts are not affected.

E. The distinctness of the inflected fissures at this period.

F. The difficulties of identifying fetal fissures in the condition of those upon the frontal and parietal regions of this specimen.

§ 311. *Fig. 777 illustrates:* A. An almost schematic condition of the paroccipital fissure, simple in form and wholly independent of the parietal, although the isthmus (opposite the end of the line from paroccipital) is slightly depressed.

B. An unusual divergence of the caudal stipe (6) and ramus (7) of the paroccipital; the former again bifurcates just over the margin on the mesal aspect.

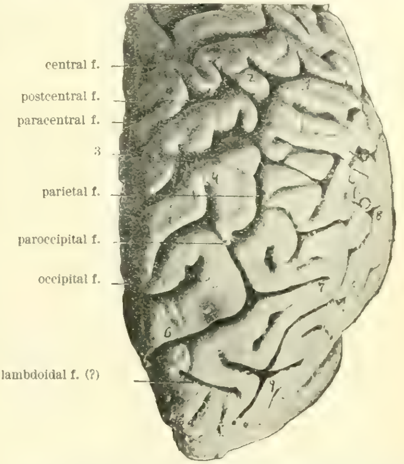


FIG. 777.—Dorso-Caudal Aspect of the Occipital Region of the Right Hemicerebrum of an Irishwoman, Thirty-Five Years Old, Exhibiting an Unusually Simple Condition of the Paroccipital Fissure; 385. × .8. Other aspects of this brain are shown in Figs 720 and 721. 1, Subcentral fissure, continuous with the parietal, but separated from the postcentral by a considerable isthmus; 2, the branch of the postcentral just below (caudad of) the isthmus does not really enter the parietal, although the shadow upon the slightly depressed narrow portion of the isthmus gives that appearance; 3, an independent fissure parallel with the postcentral; 4, cephalic ramus of the paroccipital; 5, cephalic stipe of the same; 6, 7, caudal stipe and ramus; 8, supertemporal; 9, the triradiate termination of a fissure superficially continuous with the supertemporal. The name *lambdoidal* is applied with considerable hesitation.

C. The presence of an oblique independent fissure caudad of the paroccipital suggesting the persistence of the lambdoidal of the fetus (§ 234 and Fig. 750).

D. The separation of the postcentral from the subcentral by an isthmus, 2.

E. The depth, simplicity, and cephalic trend of the occipital.

§ 312. *Continuity of the Paroccipital with the Parietal Occurs More Frequently on the Left.*—This has been noted by Ecker, Cunningham, and myself. In a recent paper (1900, *a*) I reported the results of the tabulation of 200 mated hemicerebrums, *i.e.*, from 100 individuals; all but 5 were adults, the 5 infants ranging from term to three years.

(*a*) Of the 100 left, 77 present continuity of the paroccipital with the parietal; in 23 the two fissures are separated. Of the 100 right there is continuity in only 39 and separation in 61.

(*b*) Of the 116 cases of continuity, 77 (66 per cent.) occur on left hemicerebrums, and only 39 (34 per cent.) on the right. Of the 84 cases of separation, 23 (28 per cent.) occur on the left and 61 (72 per cent.) on the right.*

§ 313. *Have the Combinations Any Significance with Respect to Age, Sex, Race, Character, or Mental Condition?*—For the purpose of testing this, the 100 individuals were grouped as in the appended Table; but the grouping is obviously unsatisfactory.

§ 314. TABLE V.—PROVISIONAL AND UNSATISFACTORY GROUPING OF ONE HUNDRED INDIVIDUALS WHOSE PAROCCIPITAL FISSURES ARE KNOWN ON BOTH SIDES.

Group.	Characterization.	Number.
A	Educated and orderly	10
B	Ignorant or unknown	50
C	Insane—various degrees	25
D	Murderers	5
E	Africans, various grades	5
F	Infants under three years	5

§ 315. In Table V. the ten members of Group A are as follows: Chauncey Wright; Prof. James Edward Oliver (3,334); a lawyer (2,870) and his wife (3,065); a teacher of mathematics (3,091); an educated farmer (3,350); a physician (3,531); a woman physician and advocate of social reforms (3,430); a woman college student (3,416); and a dentist (3,129).†

§ 316. TABLE VI.—PERCENTAGES OF OCCURRENCE OF THE FOUR PARIETO-PAROCCIPITAL COMBINATIONS IN THE SIX GROUPS OF INDIVIDUALS.

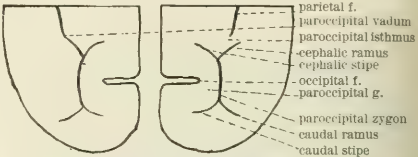
Group.	Character.	Number.	I. L. Continuity. R. Separation.	II. R. and L. Continuity.	III. R. and L. Separation.	IV. L. Separation. R. Continuity.
A	Educated and orderly	10	60%	20%	20%	0%
B	Ignorant or unknown	50	48	34	12	6
C	Insane	25	40	28	24	8
D	Murderers	5	20	60	20	0
E	Africans	5	20	60	0	20
F	Infants	5	40	20	40	0

§ 317. *Fig. 779 illustrates:* A. The complexity of this paroccipital region (compare Figs. 774 and 777).

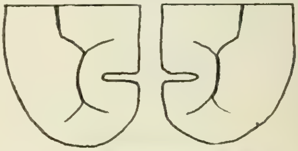
B. The narrowness of the isthmus between the paroccipital and the parietal.

C. The extension of the fissure marked 36′, over the margin of the hemicerebrum, a feature not distinctly apparent in Fig. 770.

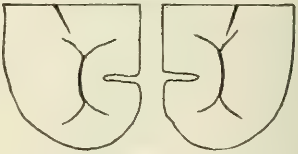
§ 318. *Commentaries on Fig. 778 and Table VI.*—Although I believe the number of mated hemicerebrums is larger than in any previous tabulation it is still too small for final results; especially is this the case with groups, A, D, E and F. Hence the following remarks must be regarded as suggestive rather than conclusive.



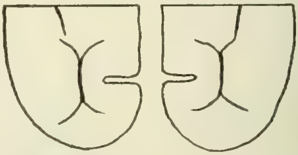
I. Left Continuity and Right Separation; 44 per cent.



II. Bilateral Continuity; 33 per cent.



III. Bilateral Separation; 17 per cent.



IV. Left Separation and Right Continuity; 6 per cent.

FIG. 778.—Diagrams of the Paroccipital Fissure.

§ 319. *Paroccipital Integrality.*—Superficially there are more cases of continuity (116) than of separation (84). But when the known or presumptive vadums are taken into account the balance of evidence seems to be the other way. It is certainly more convenient to speak of the paroccipital fissure than of the "occipital" or "posterior portion of the intraparietal complex."

§ 320. *Symmetry and Asymmetry.*—In 33 brains there is double continuity; in 17, double separation. In 44 there is right separation and left continuity; in 6, left separation and right continuity. In 50, therefore, the conditions are symmetrical and in the other 50 unsymmetrical.

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* A somewhat different ratio existed among twenty unmated hemicerebrums.

† This was the educated suicide mentioned in § 285; he was, however, highly esteemed by others besides myself.

§ 321. *Postpartum Changes.*—Condition III., bilateral separation, occurs in only 17 per cent. of the total, but in 40 per cent. of the five infants. So far as this small number goes there is borne out the conclusion of Cunningham that in many cases the union is delayed until after birth.

§ 322. *Fig. 780 illustrates:* A. The least common of the four possible combinations of the paroccipital and parietal fissures of the two sides, viz., right continuity and left separation.

B. The continuity of the parietal and postcentral fissures on both sides, but with differences that are unusual and somewhat perplexing.

C. The existence, on the right, of a clearly defined triangular fissure, 3.

D. The unusual extension of the caudal ramus of the paroccipital, 4.

E. The appearance of the trench (6) due to the pressure of an artery.

§ 323. *Parieto-Paroccipital Combinations in Individuals.*—Four different combinations are possible (Fig. 778), viz.: I. Left continuity and right separation; II. Continuity on both sides; III. Separation on both sides; IV. Left separation and right continuity. Amongst the 100 individuals tabulated (all that were accessible to me at the time), combination I. existed in 44; II. in 33; III. in 17; and IV. in only 6.*

§ 324. *May Combination I. (Right Separation and Left Continuity) be Regarded as Normal?*—Among the ten educated and moral whites (Group A) combination IV. does not occur (but neither does it among the five murderers). Combination I. occurs in 60 per cent. of Group A, in 48 per cent. of Group B (ignorant or unknown); in 40 per cent. of C (insane), and in 20 per cent. each of D (murderers) and E (Africans).

§ 325. There are many questions, general and special, that arise in connection with the paroccipital, but space permits mention of only two which were briefly discussed in my paper (1900, *a*): (1) In tabulating should not the cases in which the vadum equals in height more than one-half the greatest depth of the "parieto-paroccipital combination" be included under "separation"? (2) What weight is to be assigned to the condition in apes and monkeys where continuity is the rule, perhaps without exception? The developmental conditions in other primates than man are not known.

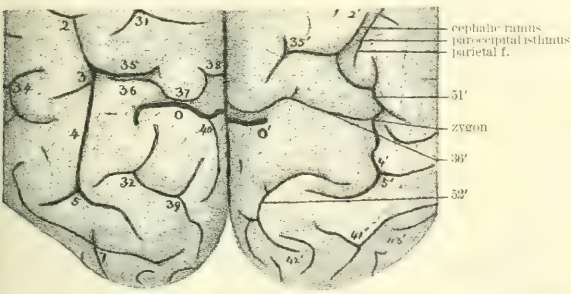

FIG. 779.—The Paroccipital Region of Chauncey Wright. On the left, the numbers correspond to those on Figs. 770 and 788. On the right, homologous parts have the same numbers with the addition of prime. 0 and 0', the occipital fissures. The left parietal fissure joins the cephalic ramus of the paroccipital at 2, where there is a vadum; on the right the isthmus is narrow and slightly depressed. The fissure marked 36, 37, and 38 is somewhat deep and separated from the occipital by a visible vadum; on the right (36') it enters the paroccipital fissure.

§ 326. *Fig. 781 illustrates:* A. The location and common form of the insula.

B. The existence of fissures and intervening gyres, radiating in general from its summit.

C. The division of the whole by a somewhat deep fissure, the transinsular (2), into a cephalic region, *preinsula* and a caudal, *postinsula.*

§ 327. *Supergyres and Subgyres.*—The ectal surfaces of two adjoining gyres are commonly at about the same level, excepting for a marked change in the general contour of the cerebrum, as, *e.g.*, at its several margins. But sometimes one gyre may be developed much more than its neighbor, and encroach upon it so as to conceal it more or less completely. The covering gyre is here called a *supergyre,* and the covered a *subgyre.*

§ 328. *Superfissures and Subfissures.*—These terms are employed herein to designate the fissures which result from the formation of supergyres and subgyres. The line of overlapping of a supergyre is a *superfissure,* as also is the line of junction of two supergyres meeting from opposite directions. A *subfissure* is one which is concealed by a supergyre, and invisible until the lips of the superfissure are divaricated.

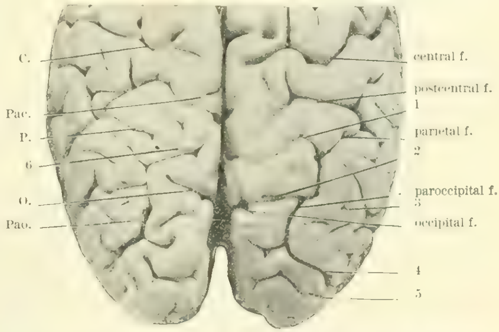

FIG. 780.—Dorsum of the Occipital Half of the Cerebrum of an Insane Swiss Woman, Fifty-Three Years Old; 2,964. × 0.6. Her mother was also insane. 1, A fissure apparently, but not really, connected with the paroccipital; 2, the cephalic stipe of the paroccipital; 3, a triangular depression; 4, an unusual and deep extension of the paroccipital; 5, undetermined fissure. On the left, 6, a vascular trench between the parietal and occipital; C., central fissure; Pac., paracentral; P., parietal; O., occipital; Pao., paroccipital.

§ 329. *Normal, human subfissures* are the circuminsular, which encircles the insula (Fig. 782), the transinsular and others crossing the surface of the insula (Fig. 781), and those which indent the ental or insular surfaces of the operculums (Fig. 783). Unusual subfissures appear in Fig. 786, after the removal of the unusual supergyre; superfissures are shown also in Fig. 787.

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* Mr. E. A. Spitzka informs me that this combination exists in the brain of Dr. Edouard Seguin. (See his papers, 1900, *a, b.*)

§ 330. The *insula* ("island of Reil") and the operculum constitute normal and typical examples of subgyres and supergyres. As may be seen in Figs. 663, 667, 752, and 782, and in the diagram, Fig. 759 (B), the insula is a part of the cortex, which, at one period wholly superficial, is gradually covered, more or less completely, by converging folds of the adjacent regions. The insula thus becomes a subgyre, while the operculum, preoperculum, suboperculum, and postoperculum are supergyres. For other supergyres see §§ 336 and 342.

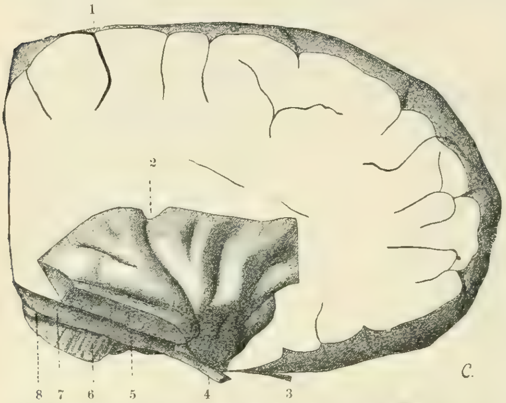

FIG. 781.—Right Adult Insula, Exposed from the Lateral Aspect; 480. × 1. 1, Central fissure; 2, transinsular fissure; 3, olfactory tract; 4, optic nerve; 5, optic tract; 6, crus; 7, pregeniculum; 8, postgeniculum.

§ 331. *Fig. 782 illustrates:* A. The existence of two zones of the lenticula, an ectal, the putamen, and a second, entad of the first, as seen in Fig. 739. There is still a third, but it does not extend sufficiently far dorsad to appear in this or Fig. 738.

B. The constitution of the insula as an elevation of the lateral region of the hemicerebrum, its cortex and medulla being continuous with the rest and with the overlapping operculums.

C. The peculiar form and location of the claustrum, a thin, subcircular disc of cinerea, between the putamen and the insular cortex, of which it is probably a dismemberment.

§ 332. The insula has notable topographical relations with (*a*) the several operculums, (*b*) the claustrum and lenticula. Although perhaps, upon the whole, most developed in man, relatively to the size of the entire brain, it is perfectly distinct in apes and monkeys, in dogs, the porpoise, and many other mammals; its comparative anatomy and its human variations are fruitful and important subjects for further observation; see especially the papers of E. C. Spitzka (1879, *a*) and (Clark, 1896).

§ 333. *The Insula in Apes.*—According to Cunningham (1897, *b*, II., 22), he and Marchand have reached independently the conclusion that in apes (orang, chimpanzee, gorilla, and gibbon) only the caudal portion of the insula is covered by the operculum and postoperculum (parietal and temporal operculums). Owing to the non-development of the other two operculums the cephalic portion of the insula is exposed like the rest of the cortex, and the "*sulcus limitans*" of Reil (part of my circuminsular fissure) is represented by a "fronto-orbital sulcus."

I regret that this interpretation is not borne out by the study I have been able to make of the material at Cornell University. There are more than fifty brains of monkeys and lemurs, and during the past sixteen years I have prepared with special care ten fresh ape brains (one gorilla, three chimpanzee, and six orang); all have been photographed; some have been sectioned or partly dissected, and one (chimpanzee) has been drawn. Still I hesitate, and am not sure that it will be possible for me to decide until there is available a fetal ape brain displaying the region in question in process of formation.

§ 334. The *operculum* is not strictly a single gyre but includes portions of at least two, the precentral and the subfrontal. It is as if the eastern half of the southern extremity of Africa were owned by the Dutch and the western by the English, each half having its own territorial designation; we might still speak of the Cape of Good Hope composed by the two countries. In general the same may be said of the postoperculum, suboperculum, and preoperculum.

§ 335. *Fig. 783 illustrates:* A. The extent to which the several operculums lap over the insula, constituting so many supergyres.

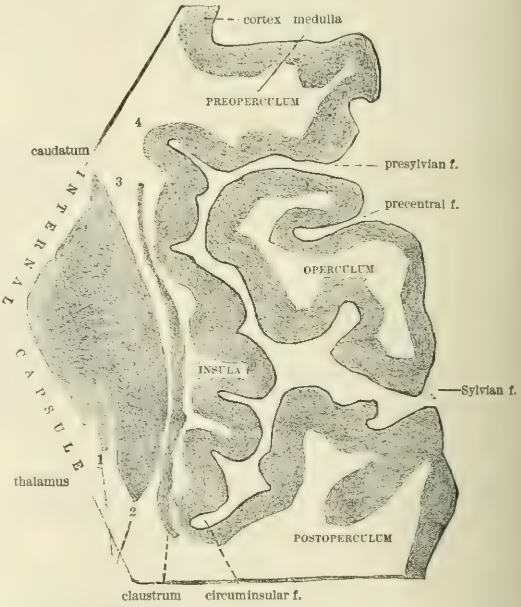

FIG. 782.—Longisection of the Right Insula and Adjacent Parts; 2,397. Enlargement of the corresponding region of Fig. 738. 1, 2, Zones of the lenticula, the lateral and larger the putamen; 3, the stratum of alba between the putamen and claustrum, sometimes (most undesirably) called "external capsule"; 4, opposite the circuminsular fissure. *Internal capsule* should be simply *capsula*.

B. The fissuration of the ental surface of the operculums

C. The distinctness of the supercallosal fissure, and the absence of a fronto marginal between it and the dorsal margin of the hemicerebrum.

D. The length of the postrhinal fissure, partly concealed by the optic nerve.

§ 336. *Subfrontal Fissure and Gyre ("Broca's convolution").*—From every point of view, anatomical, histological, physiological, psychological, anthropological, and zoological, a most interesting and important cortical region is that which Broca first showed to be related to the faculty of articulate speech. Although the conditions are often, perhaps usually, complex and perplexing, there seem to me to be a sufficiently large number of cases like those represented in Figs. 663 and 784 to warrant describing the gyre as curving about the presylvian fissure, and the fissure as zygal and **U**-shaped; the topography is much like that of the paroccipital fissure and gyre.

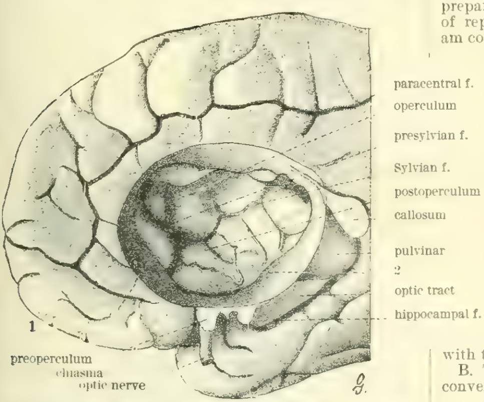

FIG. 783.—The Mesal Aspect of the Right Operculums of a Child at Term; 1,823. × 1.

Preparation. The hemicerebrum had been hardened in alcohol while resting on the meson, and hence is a little thinner and wider than natural, but thereby better suited to the desired object. A probe was pushed through from the lateral aspect at the triangular place of divergence of the Sylvian, basisylvian, and presylvian fissures; from the hole so made upon the mesal aspect, cuts were carried in various directions, cautiously, until most of the thalamus, caudatum, lenticula, and insula were removed, thus exposing the ental or mesal surfaces of the operculum, postoperculum, and preoperculum, with the intervening Sylvian and presylvian fissures.

Defects.- The inclusion of the occipital region would have rendered the figure somewhat more intelligible. The suboperculum and subsylvian fissure are not exposed; the cut surface at the ventral side should be traversed by a line starting from just cephalad of the chiasma to represent that part of the basisylvian fissure.

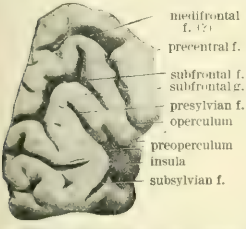

FIG. 784.—Left Subfrontal Gyre ("Broca's Convolution") and Adjacent Parts of a Man about Thirty-Three Years Old. × .5. He was the son of a clergyman, but was found dead after a drunken debauch.

§ 337. *Fig. 784 illustrates:* A. An unusually simple condition of the subfrontal gyre as a **U**-shaped region about the presylvian fissure.

B. An unusually simple zygal form of the subfrontal fissure, comparable with that in the infant brain shown in Fig. 663.

C. The complete separation of the subfrontal fissure from the precentral and the bifurcation of the latter at the point reached by the line from the name.

D. The relatively large size of the preoperculum as compared with the suboperculum; these proportions also are as in Fig. 663, and the reverse of those in Fig. 752.

E. The (probable) partial exposure of the insula in the adult brain.

§ 338. *The Subfrontal Gyre in Apes.* A paper on this subject has been published by Hervé (1888). I am not prepared to discuss Hervé's conclusions as to the degree of representation of the subfrontal gyre in apes; but I am compelled to dissent from the statement (p. 22) that of the two branches of the Sylvian fissure "ascending" and "horizontal" (corresponding respectively to my presylvian and subsylvian) the latter is the more constant.

§ 339. Recalling my own earlier erroneous interpretation of the parts, I am compelled to insist upon the necessity of exposing them fully by removing the postoperculum, and of determining whether or not a given fissure cuts through the entire thickness of the operculum.

§ 340. Supergyres and subgyres occur by exception in other parts of the cerebrum, especially the occipital (see Figs. 785 and 786), and normally in many monkeys, the *poma*, § 351, Fig. 787.

§ 341. *Figs. 785 and 786 illustrate:* A. The presence of a postcuneal fissure along the caudal margin of the cuneus; its dorsal end is free, but ventrad it has a very shallow connection with the calcarine.

B. The concealment, in the undissected brain, of the convexities of the paroccipital fissure and gyre and part of the occipital fissure by an extensive supergyre, analagous to, though probably not homologous with, the poma (occipital operculum) of monkey brains (Fig. 787).

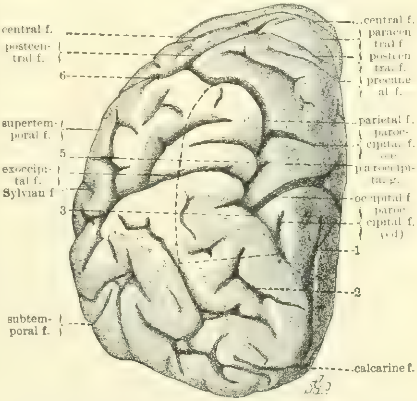

FIG. 785.—Dorso-Caudal Aspect of the Left Hemicerebrum of an Adult Male Mulatto; 322. × .8. 1, Nearly straight fissure along the caudal margin of the cuneus, the postcuneal f. (?); 2, unidentified occipital f.; 3, margin of a supergyre overlapping the paroccipital fissure, part of the paroccipital gyre, and the lateral end of the occipital fissure; 5, near the margin of the same supergyre; 6, ventral part of the postcentral f. The interrupted L-shaped line from opposite 1 to the middle of the length of the parietal fissure indicates the lines of incision by which the supergyre was removed, as seen in Fig. 786, where the two fissures are commented upon (see § 341).
For the *preparation*, see Fig. 757.

C. The conversion of the paroccipital fissure and gyre into a subfissure and subgyre.

D. The apparent continuity of the exoccipital with the occipital in the undissected brain.

E. In general, the desirability of checking all conclusions based upon the obvious features of the cerebrum, by an examination of the concealed conditions.

§ 342. The so-called "external occipital," or "external perpendicular," fissure of monkeys is a superfissure, factitious, variable, and heterogeneous, resulting from the lapping of a supergyre, the *poma* ("occipital operculum"), upon the parts cephalad of it; it may therefore be called the *pomatic* fissure.

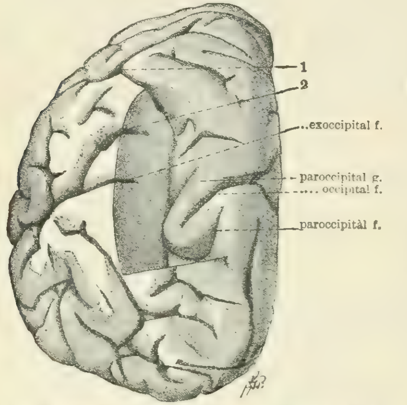

FIG. 786.—Dorso-Caudal Aspect of the Left Hemicerebrum of an Adult Male Mulatto, Partly Dissected: 322. × .8. 1, Junction of the parietal and postcentral fissures; 2, a fissure connected with the exoccipital.

Preparation.—By two incisions along the L-shaped line shown in Fig. 785 the supergyre there indicated by 3 and 5 has been removed.

§ 343. *Fig. 787 illustrates:* A. The relation of the poma ("occipital operculum") of monkeys, as a typical supergyre, to the paroccipital and part of the supertemporal, which are here subgyres.

B. The relation of the pomatic ("external occipital") fissure of monkeys, a typical superfissure, to the paroccipital and occipital fissures, which are here wholly or partly subfissures.

C. The, so to speak, factitious nature of the pomatic fissure, since it results, not from the opposition of two adjoining and approximately equal gyres, but from the lapping of one over the crests of those adjoining. As may be seen by comparing the two sides, it really comprises three distinct parts, viz., a lateral, between the pomatic margin and the ectal surface of the temporal gyre; an intermediate, coinciding with the cephalic stipe of the paroccipital fissure; a mesal, formed by the pomatic margin and the paroccipital gyre; finally, since the dorsal termination of the occipital fissure is covered by the poma, there results an apparent continuity of the pomatic and occipital fissures.

D. The continuity (depth not determined) of the paroccipital fissure with the parietal; see § 325.

E. The junction of the Sylvian and supertemporal fissures.

F. The distinctness of the "angular gyres."

G. The existence of peculiarities and complexities which, in my judgment, render monkey brains less serviceable than those of human fetuses for the elucidation of fissural problems.

§ 344. Under the various titles "external perpendicular," "external occipital," "temporo-occipital," "ape-fissure," "vordere occipital," etc., have been included several different human fissures or combinations of fissures, viz.: (A) The dorsal outcrop of an unusually deep occipital fissure; Marshall, "The Brain of a Bushwoman," *Philosophical Transactions*, cliv., p. 511, Figs. 1, 9, *h;* (B) a fissure on the lateral aspect caudad of the supertemporal, and having a general dorso-ventral direction; the *vordere occipital* of Wernicke ("Das Urwindungssystem des menschlichen Gehirns," *Arch. für Psychiatrie*, 1875, pl. v., Figs. 19 and 22, *k*); called *exoccipital* in the present article in order to avoid using the more natural mononym, *preoccipital*, already applied elsewhere by Meynert; (C) the combination of A and B,* on account of a supergyre which covers the dorsal end of the true occipital fissure (A) and permits the adjacent end of B apparently to become continuous with it, as in Figs. 785 and 786.

§ 345. No one of the fissures or fissural combinations mentioned in § 344 is identical with the pomatic fissure of most monkeys; but the exoccipital may exist in the true apes and in *Ateles* (Huxley, *Zool. Proc.*, 1861, pl. xxix.). It is doubtful whether the term "ape-fissure" is a desirable one to retain.†

§ 346. *What Significance Has the Arrangement of the Fissures?*—The query is warranted by two classes of facts, viz.: (1) with the mammals whose cerebrums are fissured a more or less definite fissural pattern has been recognized in most of the species studied in that respect; (2) the fissures of idiots are commonly peculiar in some way. There is, therefore, no reason, *a priori*, why one should not seek fissural correlation with sex, family, race, capacity, attainment, and character.

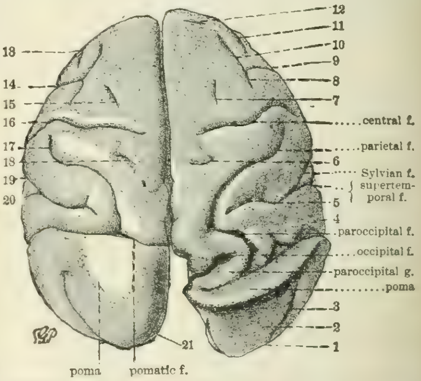

FIG. 787.—Dorso-Caudal Aspect of the Brain of a Monkey (*Macacus*), the Right Poma Lifted: 1,807. × 1. 1, Caudal end of right occipital lobe; 2, surface caudad of poma; 3, unidentified fissure; 4 (light line), line of detachment of the pomatic margin; 5, superfissure resulting from the union of the Sylvian and supertemporal; 6, postcentral (?) f.; 7–15, undetermined frontal fissures; 16, left central f.; 17, left parietal f.; 18, left postcentral (?) f.; 19, left Sylvian f.; 20, left supertemporal f.; 21, fissure on the mesal surface of the occipital lobe, seen also on the right.

Preparation.—The fresh brain was exposed in brine, and left in the base of the skull for support; on the right side, the margin of the overlapping poma ("occipital operculum") was freed by tearing the arachnoid with the syringotome (see article *Brain: Methods*), and the poma reverted and kept in position with absorbent cotton wet with brine. The whole was then placed in 95 per cent. alcohol so as to harden rapidly in the desired shape. When firm it was photographed from the dorso-caudal aspect, the lifted poma being greatly foreshortened. The parts on the left were undisturbed.

§ 347. Some idea of the problems involved and the difficulties of their solution may be gained from the comparison of the cerebrums of the two philosophers, Wright and Oliver, the Swedish carpenter, and the unknown mulatto (Figs. 664, 762, 767, 770, and 788). The first two differ markedly not merely in detail but in general aspect; architecturally speaking, the gyres of Oliver are Corinthian in style, those of Wright, Egyptian. An approximation to this is seen in the mulatto. The mechanic's cerebrum is fissured to an unusual degree and the insula completely hidden; the philosopher had a larger brain, but its lateral aspect presents an equally unusual absence of fissural complexity and the insula is exposed.

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* "The so-called ape-fissure has been so termed because it imitates in disposition the opercular [my pomatic] fissure of the apes. It is, however, not a perfect homologue of that fissure, though its presence, when it is due to the fusion of the external occipital with the internal perpendicular sulcus, is a significant sign of disturbed cerebral growth" (E. C. Spitzka, "Insanity," 1887, 286).

† For some years I have been gathering materials for the elucidation of one of the most perplexing subjects in cerebral topography, the so-called "ape-fissure," but this is not the occasion for a full presentation of either facts or opinions.

§ 348. *Comments upon Fig. 788.*—Pending the detailed study and description of this very interesting brain by the writer, to whom it has been generously loaned from the Museum of Harvard Medical School, with the consent of its preparator and first describer, Dr. Thomas Dwight, the professor of anatomy, the following points may be noted: A. The great length of this hemicerebrum as compared with that of the mulatto (Fig. 762).

B. The special length of the caudal part, whether the central or the Sylvian fissure be taken as the dividing line.

C. The height of the frontal region.

D. The apparently slight extent of the prefrontal lobe; *apparently*, because, as is shown upon the dorsal aspect (Fig. 770), a large part of this region is invisible from the side, and is of unusual width.

E. The simplicity of the visible gyres, due to the few contortions of the main fissures, and the comparative infrequency of minor ones; *visible*, because the unseen cephalic surface of the prefrontal lobe presents a much greater complexity.

F. The condition of the minor fissures as sharp incisions rather than as slight depressions, like those in the Swedish brain (Fig. 767).

G. The visibility of the insula, at least equal to that in the mulatto (Fig. 762). Whether any of this condition is due to the pressure during hardening which may have occasioned also a peculiar roundness of the temporal lobe, it is impossible to determine, and Dr. Dwight does not recall the condition of the parts when the brain was removed.

H. The great length of the supertemporal fissure, and its dorsal subdivision.

I. The bifurcation of the Sylvian fissure, constituting perhaps an episylvian and hyposylvian as in the mulatto.

J. The complete independence of the precentral and subfrontal fissures.

K. The union of the proximal parts of the presylvian and subsylvian fissures, so as to separate the pre- and postoperculum.

L. The presence of an unusual, curved fissure (14) ventrad of the subcentral.

M. The crossing of the temporal region ventrad of the supertemporal fissure by several irregular fissures (transtemporal).

N. The complication of the zygal form of the orbital fissure by a branch extending cephalad from the middle of the zygon.

O. The complete interruption of the central fissure by an isthmus which is more clearly indicated in Figs 770 and 771.

P. The fulness or "plumpness" of the gyres, remarked by Dr. Dwight.

§ 349. *Is There a Criminal Type of Fissures?*—Benedikt and others have held that, in murderers for example, there is a tendency to fissural confluence or to a condition resembling that in certain carnivora. The materials at my disposal lead me to share the doubts expressed by Donaldson (*Amer. Neurol. Transactions*, 1892, p. 54), Schwekendiek (*Amer. Jour. Neurol. and Psychiatry*, i., 569–573), and Schäfer ("Quain"), 1893, 161. Upon the whole, notwithstanding the able contributions of Dercum (1889, 1892), Mickle (1896), Mills (1886), Weinberg (1896),

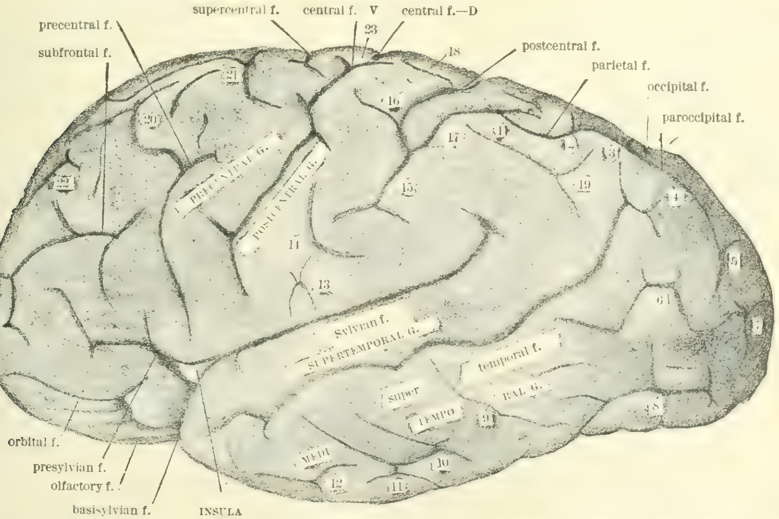

FIG. 788.—Lateral Aspect of the Left Hemicerebrum of Chauncey Wright, a Distinguished Philosophical Writer, who died in 1875 at the age of forty-five. × .85.

Preparation. The brain was removed with care (in the usual way) and hardened in zinc chloride; there seems to have been considerable dorso-ventral sinking and lateral spreading. In the absence of a cast or measurements of the cranial cavity, it is of course impossible to say how extensive this distortion has been; enough, probably, to account for the flatness of the dorsal surface, and the consequent foreshortening of the fissures of that region as seen from the side, but not sufficient to have produced the great width of the prefrontal lobes, noted under Fig. 768. The figure accompanying Dwight's suggestive remarks upon this brain (*American Academy Proceedings*, 1877, xiii., pp. 210–215) is stated to be somewhat diagrammatic, largely, apparently, for the sake of exhibiting the entire lateral aspect to better advantage.

Wilmarth and others, I am disposed to regard as premature any conclusions as to fissural correlation, and to urge renewed and systematic efforts in three directions, viz.: (1) The determination of the standard fissural pattern for the *average well-born, orderly, and educated white male*; (2) the collation of the conditions in large numbers of individuals of the other sex, of other races (especially the African), and mental and moral conditions; (3) the detailed description and portrayal of the fissures of individuals of marked characteristics.

§ 350. *The Value of Organization.*—In France there has existed for many years a "Societé mutuelle d'Autopsie." In 1890 was formed the American Anthropometric Society, which has already received the brains of Harrison Allen, Edward D. Cope, Joseph Leidy (its first president), of his brother, Dr. Philip Leidy, and Dr. James W. White. I had already prepared a "Form of Bequest of Brain" which was first executed in 1889, and which, as since amended, is here reproduced:

FORM OF BEQUEST OF BRAIN.

I, ..., now of ...., student of .... from .... to ...., and graduated from .... in ...., recognizing the need of studying the brains of educated and orderly persons rather than those of the ignorant, criminal, or insane, in order to determine their weight, form, and fissural pattern, the correlations with bodily and mental powers of various kinds and degrees, and the influences of sex, age, and inheritance, hereby declare my wish that, at my death, my brain should be entrusted to the Cornell Brain Association (when that is organized) or (pending its organization) to the curator of the collection of human brains in the museum of Cornell University, for scientific uses, and for preservation, as a whole or in part as may be thought best. If my near relatives, by blood or by marriage, object seriously to the fulfilment of this bequest, it shall be void; but I earnestly hope that they may interpose neither objection nor obstacle. I ask them to notify the proper person promptly of my death; if possible, even, of its near approach.

Signature ....

Date ....

Witness ....

NOTES.—1. A duplicate copy of this form should be filled out and retained by the testator.

2. The bequest should be accompanied by a photograph and a sketch of life or character, or a reference to published biography.

3. The testator should give notice of any change of address, not merely on account of the bequest, but also in order that copies of circulars or other publications may be sent.

4. A brain is safely transmitted in a tin pail of some liquid of nearly its own specific gravity (about 1.04) in which it will just float without either pressing on the bottom or rising above the surface. The most readily prepared is nearly saturated brine, made by dissolving in water as much common salt as it will dissolve, then pouring it off, and adding a little water till the brain is just suspended. Preservation as well as safe transportation may be assured by adding sufficient salt to water containing three, four, or five parts of commercial (forty per cent.) formalin.*

5. The lid of the pail should be secured with surgeon's adhesive plaster; the pail should be addressed as follows: *Anatomical Department, Cornell University, Ithaca, N. Y. Specimen of Natural History. Perishable.*

6. Copies of provisional diagrams of the fissures will be mailed upon application. For a statement of reasons for the study of the brains of educated persons, see Buck's REFERENCE HANDBOOK OF THE MEDICAL SCIENCES (Wm. Wood & Co., New York), VIII., 163, and IX., 110.

Besides the nine named in § 315 whose brains have already come into our possession, the "Form" has been filled out by more than fifty, including undergraduates, alumni, and teachers in this and other institutions of learning.

§ 351. *The Public should be Educated in This Respect.*—From the physiological and psychological standpoint it is clearly desirable to study the cerebrums of persons whose mental or physical powers were marked and well known.† The present condition of things is illogical and unprofitable. We scrutinize and record the characters and attainments of public men, clergymen, and friends, whose brains are unobtainable. We study the brains of paupers, insane, and criminals, whose characters are unknown or perhaps not worth knowing.

It is at once a reproach and an irreparable loss to science that the community has not yet been convinced that the preservation and study of one's brain is an honor to be coveted. Who can set a limit to the results that might have been attained from the examination of the brains of soldiers like Grant, Sherman, and Sheridan; of preachers like Beecher, Brooks, and Howard Crosby; of naturalists like Agassiz, Gray, and Jeffries Wyman; of lawyers like Tilden, Conkling, and Benjamin Butler? How long must science wait for a general sentiment such as is embodied in the declaration of an eminent historian, that science is as welcome to his brain as to his old hat, and that he wishes he had ten of them?*

§ 352. *Brain Weight.*—This interesting topic is discussed from the human side in the article *Brain, Growth of the*, but a few words may be added here as to comparative weight.†

§ 353. In *absolute* weight the human brain is exceeded by those of whales and porpoises (2,265–3,171 gm., 5–7 pounds) and of elephants (4,530 and upward, 10 pounds or more). The lowest of these figures approximates the greatest weight claimed for a *non-hydrocephalic* ‡ human brain. A negro brain described by Dr. C. Tompkins, *Virginia Med. Monthly*, January, 1882, pp. 291–293, weighed 1,983.80 (70 ounces or 4 pounds 6 ounces). Van Walsem has described (*Neurologisches Centralblatt*, xviii., No. 13, 1899) the brain of an epileptic idiot which weighed, when fresh, 2,850 gm. (90 ounces, or 5 pounds 10 ounces)!

§ 354. But in no animal other than those mentioned above is the brain as heavy as the smallest human, viz., that of a Bushwoman, 871 gm. (30.75 ounces). In a bull it was 337 gm., in a lion, 198, and in an adult gorilla only 425 (15 ounces) (Owen, iii., 144). The largest ape brain is then only half as large as the smallest normal human.

§ 355. The *relative weights* of the body and brain vary greatly according to the condition of the former at death. Most of the cases tabulated were of persons dying after more or less prolonged disease, and the figures are as follows: for 81 males, 1 to 36.50; for 82 females, 1 to 36.46; according to Bischoff, 1 to 35.20. Quain concludes that in healthy individuals dying suddenly from disease or accident, the ratio is probably about as 1 to 45. In comparing man with animals in this respect this last ratio should commonly be adopted.

§ 356. Owen estimates the adult male gorilla at 200 pounds, or 90,720 gm., and the brain would be as 1 to 213; in a bull it was as 1 to 2,000, and in a lion as 1 to 555. On the other hand, in a sparrow the ratio was as 1 to 25; and in a marmoset (*Midas*) 1 to 20 (Owen, iii., 142); and in *Jacchus vulgaris* (No. 664, Cornell University Museum), as 1 to 19. But it is to be noted that in these small monkeys, as in birds, the cerebrum is *not fissured*. Perhaps the least misleading mode of stating the case is to say that the human brain is relatively heavier than that of any animal larger than a cat in which the cerebrum is fissured.

VIII. RHINENCEPHAL.—§ 357. *Olfactory Bulb and Tract.*—These parts of the human brain have already been shown from various aspects in Figs. 663, 670, 672, 689, 751, 752, and 765. In Fig. 789 they present almost diagrammatic simplicity as a tongue-like extension from the region of the postcribrum ("anterior perforated space") more or less completely covering the olfactory fissure.

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* For other liquids adapted to the transportation and preservation of the brain, see the article, *Brain: Methods.*

† Among the individuals best adapted to subserve this object are college professors, who have usually somewhat sharply defined capacities and attainments, and are the subjects of prolonged and discriminating observation and discussion among their trustees, colleagues, and students; no professor's brain should be lost to neurological science.

* It is encouraging to know that the brain of the late George Grote, historian of Greece, has been described by John Marshall in the Jour. of Anat. and Physiol., vol. xxvii., pp. 21–68.

† The two papers of Waldeyer (1896) contain the titles of six hundred and thirty-seven books and papers relating to fissures, gyres, commissures, and brain weight, and published, for the most part, between 1879 and 1898.

‡ The brain of a Chippewa Indian squaw, eighty-five years old, rachitic, in the Army Medical Museum, Anatomical Section, No. 1,031, weighed when fresh 73.5 ounces (2,083.72 gm.), but it was *hydrocephalic*, and the curator informs me that the "ventricular liquid was probably included in the weight."

§ 358. *Fig. 789 illustrates:* A. The length of the olfactory bulb at this period, as compared with its tract, which latter is the longer in the adult.

B. The concealment of the entire olfactory fissure by the olfactory bulb; in the adult, usually, the fissure projects considerably beyond the bulb (Fig. 672).

C. The apparent continuity of the insula with the lateral root of the olfactory tract.

D. The partial covering of the insula at this period.

E. The thickness and roundness of the margin of the operculum.

F. The formation, at this period, of the presylvian fissure, constituting the cephalic limit of the operculum, but the non-existence of a subsylvian fissure.

§ 359. The corresponding parts in several other vertebrates are shown in Figs. 680 (turtle), 685 (frog), 717 (salamander), 682 and 686 (cat), and 688, 726, and 794 (sheep). Any remnant of the former anthropotomical idea that the olfactory tracts and bulbs constitute merely the first pair of cranial nerves* will probably be dispelled by noting the relative extent of the corresponding parts in still lower forms, the lamprey (Fig. 790) and the hag (Fig. 791).

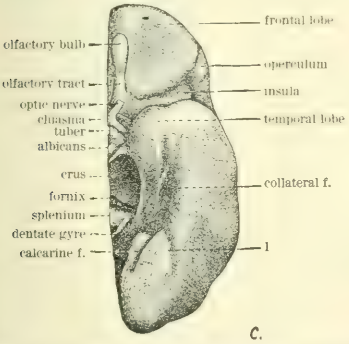

FIG. 789.—Ventral Aspect of the Left Hemicerebrum of a Fetus, Size and Age Unknown; 1,820. × 1. The lateral aspect of the same preparation is shown in Fig. 751.

§ 360. *Fig. 790 illustrates:* A. The representation of all the six definitive segments in this lowly vertebrate; the mesencephalic lobes (geminum) are prominent; the cerebellum is small and was removed with the rest of the roof.

B. The preponderance of the olfactory bulbs over the lateral masses presumably representing the cerebral hemispheres.

C. The concomitantly large size of the lateral portion of the rhinocele.

§ 361. *Fig. 791 illustrates:* A. The most distinctive character of the myxinoid brain, *i.e.*, the insignificance of the intermediate region represented in most vertebrates by the more or less prominent cerebellum and quadrigeminum; hence the entire organ naturally divides itself into a caudal portion, the oblongata, obviously an enlargement of the myel, and the brain proper, comprising four pairs of lobes narrowing caudad.

B. The large size of the olfactory bulbs, especially as seen from the ventral side.

C. The continuity of the olfactory bulbs across the meson, as seen from the ventral aspect.

D. The unusual location or trend of the mesal body provisionally named "epiphysis or dorsal sac," viz., nearer the cephalic than the caudal limit of the segment interpreted as the thalami or diencephal.

E. The vagueness of certain features due to the imperfect condition of the specimen. It was prepared by me in 1875 and the membranes, including the metatela, prematurely removed. There has not been time to prepare another, and the published accounts and figures do not clear up all the doubtful points.

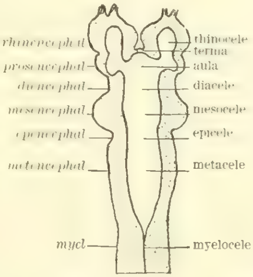

FIG. 790.—Diagram of the Brain of the Sea-Lamprey, *Petromyzon marinus*, as if the roof of the cavities was removed; enlarged. It is based upon several preparations made by me in 1874, and would be changed in some respects if made from microscopic sections; but the main features are believed to be accurate.

§ 362. *Rhinocele.*—In vertebrates generally (*e.g.*, the lamprey, Fig. 790) and in most mammals (*e.g.*, the sheep, Fig. 792), the olfactory bulb and crus contain a cavity, the *rhinocele*, continuous with the paracele and united with its opposite across the meson by the aula. Strictly and by analogy *rhinocele* should apply to the entire cavity of the rhinencephal, but for the present it is at least convenient to employ it also for either lateral portion.

§ 363. The development of the olfactory portion of the brain varies so greatly among mammals that Broca, Turner, and others have proposed groupings based thereon, viz., into *macrosmatic, e.g.*, the armadillo; *microsmatic, e.g.*, man and apes; and *anosmatic*, the porpoise, where the olfactory tract and bulb seem to be wholly absent, although the early fetal conditions are not known. The conditions in dogs are peculiar, as appears in the following abstract of P. A. Fish's paper, 1891:

1. The facts do not warrant Broca's statement as to the existence of a true ventricular axis (core of solid material in place of the primitive cavity) in the olfactory bulb, even in rat-terriers.

2. The bulb is not completely but partially occluded, or perhaps in process of becoming entirely so.

3. The cavity of the tract, in some wild forms as well as domestic, is completely closed, thereby cutting off all communication between the paracele and the cavity of the bulb.

4. The acuteness of the sense of smell is

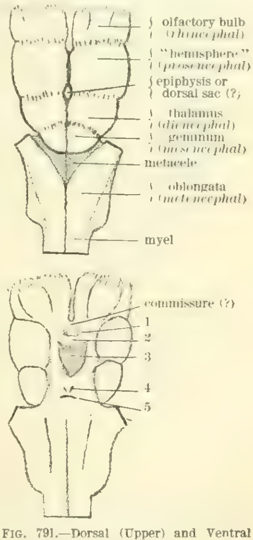

FIG. 791.—Dorsal (Upper) and Ventral (Lower) Aspects of the Brain of the Hag, *Bdellostoma*; 212. × 2.5.

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* For the present it will probably prove convenient at least to avoid modification of the accepted numerical designations of the heterogeneous cranial nerves by regarding as the "first pair" the nervous filaments which connect the olfactory bulbs with the nasal mucosa.

not essentially dependent upon the relative size of the rhinocele.

5. Atrophy is not a necessary concomitant of occlusion.

6. Domestication, and the consequent disuse of olfaction as a means for procuring sustenance, may be a factor in promoting occlusion.

7. In the classifications of Broca and Turner the dog seems to hold an anomalous position, in that he gives every external evidence of macrosmatic power; but by the almost total occlusion of his rhinocele he approaches structurally the conditions found in the microsmatics. Physiologically he is macrosmatic; morphologically he is microsmatic.

§ 364. *Precommissure.*—As stated in §§ 45 and 210, this fibrous bundle, single at the meson, soon divides into a cerebral portion (*pars temporalis*) and an olfactory (*pars olfactoria*). The gross relations of the two are well shown in Fig. 792. For the microscopic arrangement of this and other fibrous constituents of the olfactory apparatus see the article *Brain, Histology of the.*

§ 365. *Fig. 792 illustrates:* A. The divergence of the olfactory and cerebral divisions of the precommissure just laterad of the meson.

B. The relatively large size of the olfactory division in the sheep.

C. The large size of the rhinocele, but the narrowness of the strait connecting it with the precornu.

§ 366. *Crista.*—In the cat, adult as well as fetal, the caudal or celian aspect of the terma, between the columns of the fornix, presents (Fig. 686) a mesal hemispherical body which is translucent when fresh. In some lower vertebrates it seems to be represented by a membranous mass. It has been observed in comparatively few forms, and its structure, connections, and significance are undetermined. I have never seen it in adult human brains, but it is perfectly distinct in the preparation represented in Fig. 793. If there is a rhinencephalic segment the crista is to be regarded as one of its constituents.

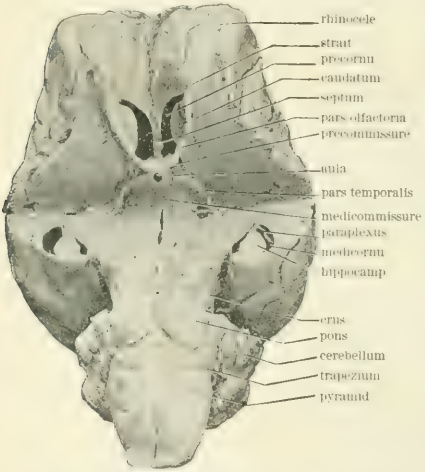

FIG. 792.—Brain of Sheep Dissected to Show the Two Divisions of the Precommissure; 2,653. × .9. Prepared by P. A. Fish. The cerebrum was cut from the ventral side in two planes meeting at about a right angle along the line indicated by the shadow just caudad of the line from the word *medicommissure*. The cephalic slope was then very carefully sliced to a deeper level, so as to leave the precommissure in relief. Unfortunately the *pars olfactoria* on the left (right of the picture) has since been broken, accounting for the interruption in the figure. Just within the aula may be dimly seen the crista. Compare with the medisected brain (article, *Brain: Methods*), and that of the cat (Fig. 686).

§ 367. *Fig. 793 illustrates:* A. The presence of the crista in a child at term.

B. The dorsal limitation of the aula and the two portas by the line of reflection of the endyma constituting a ripa.

C. The narrowness of the body of the fornix as compared with that of the cat and most other mammals.

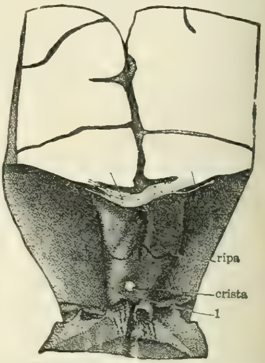

FIG. 793.—The Crista and Adjacent Parts of a Child at Term; 4. × 1.5.

Preparation.—After transection at about the middle of the diacele, the thalami were torn from their continuity with the fornix, leaving the irregular surface at and ventrad of 1. The lateral parts were then removed, as indicated in the drawing. The paraplexus was torn from the margin of the fimbria, constituting the lateral part of the fornix; the short line at the right ascends from the fimbria, crossing the intervening space, paracele. On the left the similar line begins more nearly at the middle of the fornix, and crosses first the callosum itself, and then the callosal fissure. Before photographing, the crista was touched with white paint.

Defects. The brain was ill preserved, and broke apart during dissection; the shading is too heavy.

D. The division of the caudo-ventral surface of the fornix, by the ripa mentioned under B, into an entocelian area, covered by endyma and forming the cephalic wall of the aula and the two portas, and an ectocelian area, covered by pia, the dorsal or fornical layer of the velum.

§ 368. *The Word Rhinencephalon Used in Several Senses.*—Some confusion may be avoided if it is clearly recognized that one and the same word has at least five different significations.

1. Owen applied *rhinencephalon* to the two olfactory bulbs and their tracts (or crura) without apparent reference to any mesal or connecting constituents.*

2. Turner proposed (1890) to regard the prosencephal as divided horizontally by the rhinal fissure (olfactory and postrhinal) into a ventral portion, the rhinencephalon, and a dorsal, the pallium.

3. Shäfer proposed (Quain, 1893, 160) to include under rhinencephalon the remainder of the so-called "limbic lobe" (the hippocampal gyre), and the callosal or "*gyrus fornicatus*" †

4. His considers (1893) that the bulbs and tracts, the precribrums ("anterior perforated spaces") and some other parts, under the name rhinencephalon, constitute one of three components of the dorsal zone of the most "anterior" segment, which he names *telencephalon.* This view has been adopted by the Anatomische Gesellschaft and is indicated in the Table in the article, *Brain, Development of;* see also my Table I.

5. In the report of the Committee on Anatomical Nomenclature which was adopted by the Association of the American Anatomists in 1897 (*Proceedings*, p. 47) the rhinencephalon was regarded as a definitive segment consisting of the olfactory bulbs and tracts and some other parts united across the meson by the pars olfactoria of the precommissure, the lateral cavities being connected

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* The mesal contact or coalescence of the bulbs in frogs and toads, and (as observed by Mrs. Gage, 1895) in certain turtles and birds, is a secondary condition that has no bearing on the segmental constitution of the parts.

* Since the name and notion of a "*lobus limbicus*" seem to be sometimes adopted without adequate inquiry, I cannot refrain from pointing out that, as is clear in Shäfer's diagram (Fig. 109), its alleged boundaries are not continuous in man, and I am not aware that they are in any animal.

by the mesal aula. The other constituents of the rhinencephal are named in Table I. (See above § 713).

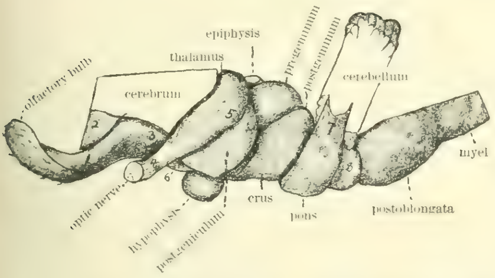

FIG. 794.—Left Side of the Sheep's Brain After the Removal of Portions of the Cerebrum and Cerebellum, So as to Display the Segmental Constitution of the Organ. (From "Physiology Practicums"; compare Fig. 688.)

1, 3, Olfactory tract; 2, a part of the pallium which has not been cut; 4 (indistinct), chiasma; 5, pregeniculum (external or anterior geniculate body), distinct in man but here little more than a lateral portion of the thalamus; 6, tuber (*cinereum*), the slight convexity to which the hypophysis is attached; 7, medipeduncle; 8, trapezium.

The short lines on the surface of the olfactory bulb represent the olfactory nerves. The cut end of the left optic nerve is dotted to indicate its fibrous structure.

Excepting the unshaded areas, representing cut surfaces, all the parts seen in this figure were covered by pia.

Preparation. The cerebellum is left of its natural height, but the cephalic and caudal convexities are sliced away so as to expose the parts which are overhung by them. The cerebrum has been cut down to the level of the thalami; the caudal portion cut away along the oblique line of its projection over the part marked 5; the lateral portion so as to expose the part marked 3; also the cephalic projection which overhangs the olfactory bulbs.

§ 369. *Commentaries on Fig.* 794.—Besides facilitating the recognition of certain important parts and their relative positions, this figure well illustrates the *segmental constitution* of the brain, which is obscured in the entire organ by the preponderance of the cerebrum and cerebellum. There is a series of more or less distinct masses demarcated by constrictions of greater or less depth. Admitting that there is still some doubt as to number and limits of the segments, the following assignments may be accepted provisionally:

Olfactory bulbs and tracts	RHINENCEPHAL.
Cerebrum	PROSENCEPHAL (fore-brain).
Thalami, epiphysis, hypophysis, chiasma, and geniculums	DIENCEPHAL (inter-brain).
Geminums and crura	MESENCEPHAL (mid-brain).
Cerebellum, pons, and preoblongata	EPENCEPHAL (hind-brain).
Postoblongata	METENCEPHAL (after-brain).

See the fuller Table on page 153.

§ 370. *Is there a Rhinencephalic Segment?*—That I am at present disposed to answer this question in the affirmative is indicated in diagrams (Figs. 674 and 675), Tables (I. and II.), and remarks (§ 45) in the earlier part of this article; see also Figs. 790, 791, and 794. The whole subject is still under discussion and likely to be for some time to come, and this is not the occasion for detailed argument. There may be stated here, however, three facts that may not be familiar to all students of normal human anatomy:

1. In the lamprey and hag, although the olfactory bulbs are paired, the olfactory sac and nostril are single and mesal.

2. In the lancelet (*Amphioxus* or *Branchiostoma*) the olfactory bulb is single and approximately mesal, although, like several other organs of this peculiar vertebrate, not quite mesal.

3. In the malformation called monophthalmia or cyclopia (see Fig. 712 and the article *Teratology*), not only the cerebrum but also the olfactory portion of the brain may be single and mesal. A very instructive case is described and figured by Cunningham and Bennett, Royal *Irish Acad. Trans.*, xxix., 101–122.

§ 371. *Limits of the Rhinencephal.*—These were not defined in the report adopted by the A. A. A., and cannot yet, perhaps, be determined with accuracy. But as an individual I may here express the opinion that in mammals the caudal boundary coincides practically with the origin of the medicerebral ("middle cerebral") artery, or with the place of junction of the Sylvian fissure with the "rhinal," including by this the olfactory and the postrhinal (amygdaline) together. This leaves the tip of the temporal lobe, the lobus hippocampi, and the whole hippocampal gyre as parts of the prosencephalic pallium, although they may contain the cortical centres of the olfactory sense. In the lower mammals, the elevation sometimes called *protuberantia natiformis* similarly lies caudad of the rhinencephalic boundary.

§ 372. *Postrhinal Fissure*—Although regarded as lying within the pallium and thus in the prosencephal rather than the rhinencephal its associations are such that a few words may be added here as to its apparently different locations in man and in the lower mammals. In the latter both it and the olfactory fissure are visible from the lateral aspect. But in the lower monkeys the greater development of the pallium crowds them to the ventral side, and in man and apes the postrhinal fissure becomes actually mesal (Figs. 765, 766).

IX. MENINGES (THE ENVELOPES OR MEMBRANES OF THE BRAIN AND SPINAL CORD).—

§ 373. *Definitions.*—*Meninges* is the plural of *meninx*, from the Greek *μῆνιγξ*, signifying any membrane or coating, as of the eyeball, and even the scum upon milk or wine; but, as stated by Hyrtl ("Onomatologia," p. 324), the word was restricted by Aristotle ("Hist. Anim.," lib. i., cap. 16) to the coverings of the brain (and myel?), and the limitation has been since maintained. The synonyms of *meninx* are: Fr., *méninge;* It. and Sp., *meninge;* Ger., *Hirnhaut.*

§ 374. *The Three Meninges.*—Nearly all anatomists recognize three chief membranous envelopes between the substance of the neuron (brain and spinal cord) and the craniospinal canal, viz.: an ental, the *pia;* an ectal, the *dura;* an intermediate, the *arachnoid.* Their relative positions when the cranium is opened are indicated in Figs. 795 and 796. Properly speaking the pia pertains to the neuron, and the dura to the craniospinal canal, while the arachnoid has more or less varied relations to both the other meninges. All three present differences according to their location within the cranium or the spine, and there are transition conditions in the cephalic portion of the latter which are not yet fully made out.*

§ 375. The term *pachymeninx* (tough envelope) is sometimes used for the dura, irrespective of the recognition of a parietal layer of arachnoid. In like manner *leptomeninx* (tender envelope) is sometimes used for the pia and the commonly admitted visceral layer of arachnoid. The pathological terms, *pachymeningitis* and *leptomeningitis* are derived from these words.

§ 376. *Fig. 795 illustrates:* A. The successive coverings of the brain, hairy scalp, periosteum, calva

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* The conditions of investigation of the meninges are peculiar. The pia and arachnoid are relatively delicate; they are easily torn and their attachments ruptured; they are surrounded by an unusually tough membrane, the dura, and the whole is enclosed within a case of bone, which must be sawn or otherwise forcibly opened by measures which are almost sure to rupture the pia and arachnoid. It is much to be desired that the subject be reviewed by some anatomist having the use of a mechanical bone-cutting apparatus, *e.g.*, the electro-osteotome of the late Dr. M. J. Roberts.

(calvarium) dura (ental periosteum), arachnoid, and pia.

B. The shadowy appearance of a fissure covered by the piarachnoid and the sharper outline when it is removed (Fig. 802).

C. The difficulty of separating the arachnoid from the pia; in a transection of a fissure, however, the former will be seen to pass across the fissure from gyre to gyre, while the latter, with blood-vessels, dips into the fissure as a fold (Fig. 735).

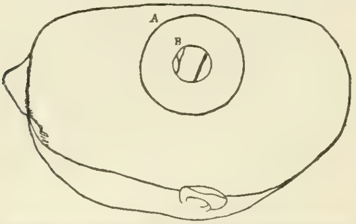

FIG. 795. Outline of the Dorso-Lateral Aspect of the Left Half of the Head of an Adult Man, with the Brain Exposed in the Region of the Central Fissure; 811. × .3.

Preparation.—The entire head was alinjected by continuous pressure for a week, and medisected as shown in Fig. 670. From the general region of the central fissure was removed a disc of the scalp about 6 cm. in diameter (A); in the centre of the area so exposed, a disc of the calva (calvaria, cranial vault) was removed with a trephine 2.5 cm. in diameter, and the corresponding disc of dura cut out (B). The further preparation of the specimen is described under Fig. 796; the present outline is mainly given in order that the region may be located approximately upon the head.

D. The presence on the ental surface of the piarachnoid of a pial fold, the *ruga*, lying in the fissure.

E. The minutely punctate aspect of the depiated cortex by reason of the extraction of minute vessels entering from the pia. The ental surface of the pia, here represented smooth, should have a flocculent appearance, called *tomentum*, from the attachment of these vessels.

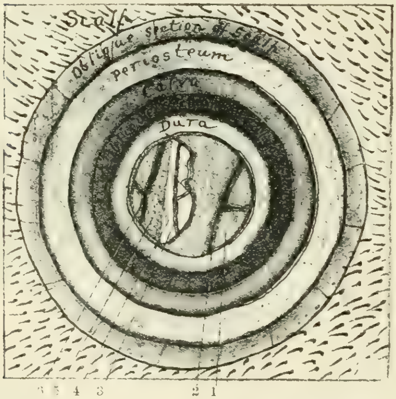

FIG. 796.—The Several Coverings of the Brain Exposed as a Series of Terraces; 811. × .9. 1, The arachnoid, the ectal layer of the piarachnoid; 2, a fissure, still covered by the piarachnoid; 3, ruga, the fold of pia that has been pulled out of the fissure 6; 4, ental (pial) surface of the flap of piarachnoid everted from the surface of 5, a gyre, between fissures 2 and 6; 6, a fissure from which the ruga and adjacent piarachnoid have been removed.

Preparation.—The region here included is a square of the region shown in Fig. 795. The outer line corresponds with the circle A, and the inner with circle B. The scalp was divided obliquely so as to expose a converging surface. A disc of periosteum was cut out a little smaller than the ental line of the scalp. The original trephined orifice in the calva was then enlarged with nippers, so as to leave a converging surface, the ectal circle a little smaller than the hole in the periosteum, and the ental about as much larger than the hole in the dura. Two fissures could be seen; over the caudal the piarachnoid was left undisturbed; at the cephalic side of the dural orifice a semilunar flap was lifted and reflected so as to expose the ental surface and the fissure and adjoining gyres which it had covered.

§ 377. *Fig. 797 illustrates:* A. The subcylindrical form of the myel, and the relations of the areas of alba and cinerea at this level; see the article, *Spinal Cord.*

B. The existence of a dural sheath (theca) of the myel, independent of the periosteum, the two being united in the cranium.

C. The somewhat loose adhesion of the arachnoid to the dura, leaving slight and scattered subdural spaces.

D. The presence of the *septum posticum* at this level; it is said (Shäfer, iii., 188) to be most perfect in the cervical region, and more or less incomplete farther caudad.*

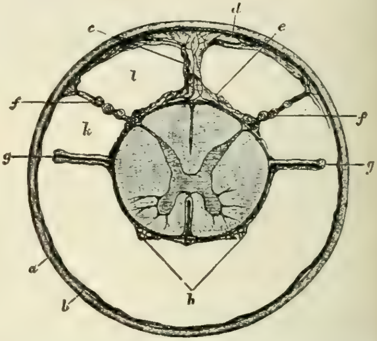

FIG. 797.—Transection of the Myel and Its Meninges in the "Upper" Thoracic Region. (Enlarged somewhat from Key and Retzius, Taf. i., Fig. 7, after Shäfer: Quain, iii., Fig. 132.) *a*, Dura (not the spinal periosteum, but representing the ental layer of cranial dura); *b*, arachnoid; *c*, septum posticum; *d*, *e*, *f*, trabeculæ in the subarachnoid space, those at *f* supporting the dorsal (posterior) nerve roots; *g*, ligamentum denticulatum; *h*, ventral (anterior) nerve roots, cut off; *k*, *l*, subarachnoid spaces. The pia is not designated, but may be recognized as the double outline of the myel dipping into the dorsal fissure as a narrow septum and into the ventral as a fold.

Note.—The foregoing is substantially the description in Shäfer. But some of my observations lead me to suggest that the spinal, like the cranial, arachnoid comprises two layers, a dural and a pial, connected by the reflected layers of the septum posticum. This view, however, would homologize the space *k*, *l*, with the intrarachnoid space of the cranium, and hence their free communication with the postcisterna would be difficult to explain.

E. The size of the subarachnoid space traversed by the spinal nerve roots, the trabeculæ, and the *ligamentum denticulatum.*

F. The location of the *ligamentum denticulatum* at either side of the myel. This is a fibrous band connected with the pia, and reaching the dura by a triangular extension in the intervals between the nerve roots; but opposite the roots (as in this figure) it is narrower, and does not reach the dura.

§ 378. *Dura.*—This mononym is rapidly replacing *dura mater* and the German *harte Hirnhaut.*† As shown in Figs. 796, 799, and 804, the cranial dura is apparently a single sheet, dense, strong, fibrous, and unyielding, lining the bones and constituting their ental periosteum (endocranium). But a closer examination detects two layers, an ectal and an ental, which gradually separate in the cephalic part of the cervical region, and in the spine maintain diverse relations, the one with the canal, the other with the myel.

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* *Septicum posticum* is an undesirable term, but *septum dorsale* might be confounded with the prolongation of the pia into the dorsal fissure of the myel.

† The reduction of the polyonyms, *pia mater* and *dura mater*, to the mononyms pia and dura was urged by me twenty years ago (1880, *f*). The use of pia and dura, and of the natural adjectives, pial and dural, has now become quite general. The simplification has been recommended by the Association of American Anatomists (December 27th, 1889), by the American Association for the Advancement of Science, 1890 and 1892, and by the American Neurological Association, June 5th, 1896.

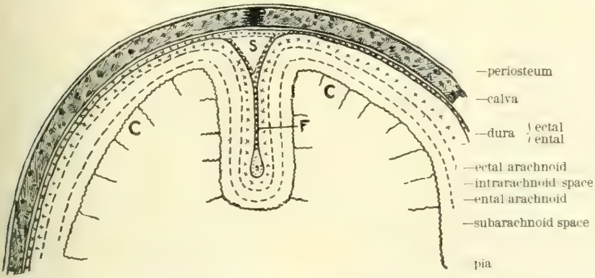

FIG. 798.—Schematic Transection of the Parietal Region of the New Born, to show the Relations of the Meninges to the Cerebrum and Cranium. (From Langdon, 1891.) C, C, Cerebrum; F, falx; S, longitudinal sinus; xxx, subserous connective tissue between the dura and the ectal arachnoid.

*Defects.** The mesal dark area dorsad of S (the longitudinal sinus) represents the ligamentous connection of the two parietal bones; it should be continuous with the periosteum and ectal dura. The "subserous dura," between the dura and the arachnoid, represented by the series of crosses, is made too wide in proportion.

§ 379. *Theca.*—The ental or myelic portion of the spinal dura constitutes a fibrous tube, the theca. It is considerably longer and larger than the myel itself, and separated from the periosteum constituting the wall of the canal by venous plexuses and much areolar tissue. The cavity between the pia and the dura is occupied by cerebro-spinal fluid (neurolymph), and is divided by the curtain-like arachnoid into the spaces subdural and subarachnoid. Within the latter the myel, closely covered by pia, is suspended, being kept in position by a ligament on each side, *ligamentum denticulatum* (Fig. 797), which fixes it at frequent intervals to its sheath, and by the roots of the spinal nerves (Fig. 797, *f*), which cross the space from the surface of the myel to the intervertebral foramina.

§ 380. *Fig. 798 illustrates:* A. The existence of two layers of dura in the cranium, the one corresponding with the periosteum of the spinal canal, the other with the dural sheath of the myel, Fig. 797, *a*.

B. The existence of two layers of arachnoid—an ental or pial, and an ectal or dural.

C. The propriety of regarding the so-called subdural space as an intrarachnoid space, analogous with the serous sacs in other parts of the body (see § 399).

§ 381. *Fig. 799 illustrates:* A. The formation of a nerve root from the union of several funiculi or rootlets.

B. The extension of the myelic dura upon the root at its exit from the spinal canal, to be lost in the sheath of the nerve.

§ 382. *Epidural Space.*—In the spine, since there are two layers of dura, an ectal (periosteal) and an ental (myelic), the interval between them constitutes an epidural space. In the figures this is nowhere clearly shown, but it may be represented in Fig. 797 by drawing around the present ectal outline, the myelic dura, a second at a little distance therefrom; the interval would be the epidural space.

§ 383. Two questions naturally arise in connection with the epidural space.

1. Does it communicate with the subdural space? If so, where?

2. If not, what is the source of the liquid occupying the space, and what is its nature?

§ 384. *Fig. 800 illustrates:* A. The relation of the dura to the cranium as a complete lining of considerable thickness.

B. The relation of the falx (1) and falcula (13), as mesal extensions of the dura, to the tentorium (8) as a transverse extension.

C. The tent-like form of the tentorium, the lateral margins coinciding approximately with the long axis of the cranium, the intermediate portion rising toward the meson at an angle rapidly increasing from the occiput cephalad.

D. The inversion of the falcula as compared with the falx.

E. The general arrangement of the more prominent fibres of the falx; there is a marked divergence or radiation from about the place of intersection of the free margins of the falx and the tentorium.

F. The locations of the principal sinuses along the lines of attachment of the dural folds to one another or to the cranium.

G. The direction of the current in the principal sinuses: in the longitudinal (2) and tentorial (6) (with the falcial) (4) toward the torcular; in the lateral (9), toward the exit in the base of the skull at the jugular vein (4), in the superpetrosal and subpetrosal (10, 11) to the lateral.

The entrance of the supercerebral veins into the longitudinal sinus at the points indicated by the black spots in the course of the latter and at others not indicated.

§ 385. *Tentorium.*—The cerebral region of the cranium is partitioned off from the region containing the cerebellum by a fold of the ectal layer of the dura, which, from its arched shape, is called the *tentorium* (*cerebelli*), Fig 800. See also the article *Brain, Circulation of.*

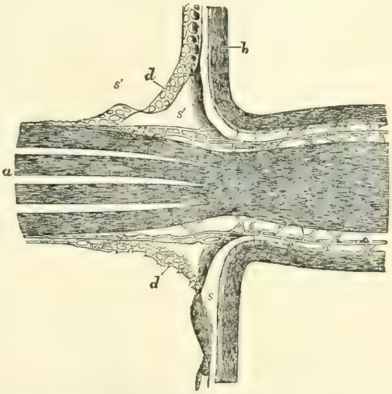

FIG. 799.—Section, Lengthwise, of a Ventral Nerve Root at Its Place of Exit from the Spinal Canal Enlarged. (From Key and Retzius, Taf. i., Fig. 10; after Shäfer: Quain, iii., Fig. 128.) *a*, Four funiculi uniting to constitute the root; *b*, dura reflected upon the root at its emergence through the intervertebral foramen (the periosteum is not shown); *c*, arachnoid; *d*, reticular lamella of the arachnoid reflected upon the root (compare Fig. 797, *f*); *s*, subdural space *s'*, subarachnoid space.

The tentorium exists in most, if not all, mammals, but not, so far as I am aware, in other vertebrates; in the carnivora it is ossified.

§ 386. *Falx.*—From the cerebral side of the tentorium extends cephalad a mesal duplicature of the dura, the falx, well named from its sickle shape (Figs. 800 and 801). The narrower cephalic end is attached to the *crista galli.* The distance between the free margin of the falx and the callosum increases cephalad. The relations of the falx to the longitudinal and falcial sinuses are shown in Figs. 800, 1; 801.

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*Dr. Langdon informs me that the cut does not represent the original drawing quite fairly in some respects.

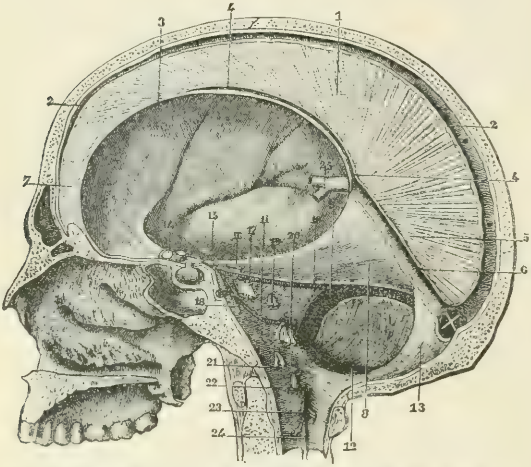

FIG. 800.—Mesal Aspect of Right Half of Medisected Skull Retaining the Dura. × .5. (From Sappey, iii., Fig. 462; after Shafer: Quain, iii., Fig. 129.)

Defects. As usual, there is no indication of the change that occurs at or near the foramen magnum, by which the apparently single dura of the cranium divides into a true dura related to the myel (Fig. 797) and a spinal periosteum; see, however, Shäfer (Quain), iii., Fig. 182. The region of the postoccipital sinus (12) is so heavily shaded as to give the impression of its considerable width; as shown in the original of Sappey, this sinus is no longer than the subpetrosal; according to Browning this is merely a constituent of the irregular basilar plexus of venous channels. The vein of Galen (25) here joins the tentorial sinus at an angle of about 45°; really, as shown in Fig. 801, it curves about the rounded splenium and joins at nearly a right angle.

1, Falx; 2, longitudinal sinus; 3, concave ventral margin of falx; 4, falcial (inferior longitudinal) sinus; 5, base of the falx where it joins the tentorium; 6, tentorial (straight) sinus or *s. rectus*; 7, cephalic, narrow end of falx, a little dorsad of the *crista galli* to which it is attached; ventrad of the line is a frontal (air) sinus, seen also in Fig. 670; 8, right side of tentorium, sloping latero-ventrad from the attachment to the falx to the side of the cranium along the lateral sinus (9); X, the torcular, the place of confluence of the two lateral sinuses, the longitudinal and the falcial; 10, the superpetrous (superior petrosal) sinus; 11, the subpetrous (inferior petrosal) sinus; 12, postoccipital (posterior occipital) sinus; the arrows indicate the direction of the blood in the larger sinuses; the lateral sinus is continuous with the entojugular vein; 13, falcula (falx cerebelli); 14, optic nerve; 15, oculomotor nerve; 16, trochlearis nerve; 17, trigeminus (trifacial) nerve; 18, abducens nerve; 19, facial and auditory nerves; 20, glosso-pharyngeal, vagus, and accessory nerves; 21, hypoglossal nerve; 22, 23, first and second cervical nerves; 24, cephalic end of the *ligamentum denticulatum* (see Fig. 797); 25, union of the velar veins to constitute the vein of Galen opening into the tentorial sinus (see Fig. 801).

§ 387. *Falcula.*—This name (wrongly printed *falcicula*) was proposed by me as a mononym for *falx cerebelli,* designating the mesal fold of dura which extends ventrad from the tentorium to the *foramen magnum,* where it bifurcates. It is vaguely shown in Figs. 800 and 801.

§ 388. *Fontanels* (Fr. *fontanelles*).—These are the intervals between the corners of the infantile parietal bones before these corners have formed sutural union with the adjacent bones. There are six fontanels, two mesal and two pairs of lateral. The lateral, at the cephalic and caudal angles of the ventral border of the parietal bone, are small, irregular, and of comparatively little interest. The two mesal fontanels are at the ends of the sagittal suture; their more common designations, *anterior* and *posterior*, may appropriately give place to *prefontanel* and *postfontanel.*

§ 389. *Analogy of the Fontanels with the Telas.*—The structure of a tela was described in § 22. But since, in mammals at least, the telas are always more or less closely adherent to adjacent parts, and their margins are easily detached, their relations are sometimes not clearly appreciated. But if an infant or fetal cranium be divided across the prefontanel diagonally so as to include either parietal bone and the opposite frontal, the cut edge will present three layers, viz., an ental, the dura, representing the endyma; an ectal, the pericranium, representing the pia; an intermediate, the bone, representing the nervous parietes. At the fontanel this third element is absent, and the conjoined dura and pericranium contribute a membranous area quite comparable with a tela and available for illustration thereof.

A defect in the analogy is this: The cranial bone is of nearly uniform thickness, and thins out at the margin of the fontanel. But in the brain, although the immediate margins of the telas may be thin, the general parietes are commonly very massive, and there is usually a parallel zone specially differentiated, *e.g.*, the habena.*

§ 390. *Fig. 801 illustrates* (in addition to the points mentioned under Fig. 687 and in § 66): A. The degree of retention of the dura in this specimen is greater than with any brain ever seen or heard of by me. The brain was most skilfully removed, according to my directions, by Prof. W. C. Krauss, a former student (see the article *Brain: Methods*).

B. The existence, in the caudal three-fifths of the cerebrum, of a distinct and considerable mesal depression, containing the longitudinal sinus, so that here the retreating surface of the dura is seen beyond its dorsal cut margin; presumably this corresponded with a mesal thickening of the cranium.

C. The distinctly sickle-shape of the mesal extension of the dura between the two hemicerebrums, whence its name *falx.*

D. The non-correspondence of the width of the falx with the area dorsad and cephalad of the larger part of the callosum.

E. The location, form, and extent of the medicisterna (*cisterna ambiens*), the irregular space between the cerebellum, the splenium, and the geminums, roofed by the arachnoid and tentorium.

F. The location, form, and extent of the ventricisterna (*cisterna intercruralis*), between the crura, the pons, and the tuber (*tuber cinereum*), infundibulum and hypophysis. It forms a very deep indentation of the ventral outline of the brain, corresponding with the cranial or mesencephalic flexure (Fig. 671). It is bridged by the arachnoid, following substantially the line of the dura, and thus includes the arteries of this region.

G. The location, extent, and form of the postcisterna (*cisterna magna cerebello-medullaris*), the interval between the dorsum of the oblongata, the cerebellum, and the adjacent portion of the cranium, or strictly the ectal layer of arachnoid in that region, represented by the black line marked 10 (see Figs. 806 and 807, § 408).

H. The location of the metapore (foramen of Magendie), the orifice in the metatela (*tela choroidea inferior*), constituting the roof of the metacele or metencephalic portion of the "fourth ventricle" (see §§ 78–83). In this specimen its relations are complicated by the postcerebellar artery, a loop of which lies just dorsad of it (see under Defects).

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* It is proper to add that, although this analogy between the telas and the fontanels had already occurred to me, I was reimpressed with it on listening to an admirable lecture upon the anatomy of the brain by Prof. D. K. Shute, at the Columbian Medical College, Washington, D. C., December 16, 1889.

I. The location of the postcerebellar artery. This is not named on the figure and is imperfectly shown. The central portion, from its origin at the vertebral, is invisible here, but shows in Figs. 691 and 806. Just at the side of the metapore it turns sharply upon itself, forming a loop, somewhat as in Fig. 806; but in the present figure the peripheral portion of the artery alone is seen, and looks as if it began in the metapore. The two principal divisions are as here represented. There is apparently considerable variation in the course and subdivision of this vessel.

J. The length of the longitudinal sinus, equalling nearly the greater curvature of the cerebrum; its cephalic end was probably not quite reached.

K. The presence of the falcial sinus (2) along the ventral, free margin of the falx. This is said to be often wanting. I suggest that the alleged absence of this sinus in the fetus sometimes may be due to its non-detection.

L. The straight course of the tentorial sinus in line with the falcial, along the ventral margin of the caudal fifth of the falx, where the latter is continuous with the tentorium (Fig. 800, 8). The tentorial sinus is not named or otherwise designated on this figure, but in Fig. 800 it it is numbered 6; it is also called straight sinus or *sinus rectus*.

M. The junction of the mesal longitudinal and tentorial sinuses at the torcular (Herophili). The course of the lateral sinuses thence is indicated in Fig. 800.

N. The location of the right velar vein (3) between the splenium of the callosum and the conarium, and its junction with its opposite at the point indicated by the circular spot at the edge of the splenium, just in line with the dotted line from that word. The two velar veins form the short vein of Galen.

O. The brief course of the vein of Galen about the splenium, and its entrance at 4 into the tentorial sinus, at the place of continuity of the latter with the falcial when this is present.

P. The location of the right precerebral artery (anterior cerebral). Branches of this are seen dorsad and cephalad of the callosum. The main trunk extends dorso-cephalad from the chiasma. The dark spot between the dotted lines leading from the words *terma* and *precommissure* represents the junction of the two precerebral arteries at the meson; in some cases they are separated by a considerable interval and communicate by a slender precommunicant artery. Here, however, they unite by their full width and again diverge.

Q. The origin of the termatic artery from the place of junction of the two precerebrals; its course, parallel with the terma and copula, then around the genu at least to the dorsum; its short branches to the terma and adjoining parts of the hemicerebral meson.

R. The location of the postcerebral artery. The beginning of this, severed from the basilar, is represented by the circular spot between the hypophysis and the convexity of the pons. From it are seen small arteries entering the crura. For the two large vessels represented in the ventricisterna, see under *Defects*.

§ 391. *Pia.*—This was formerly more often called *pia mater*, sometimes also *meninx vasculosa* (Ger., *dunne*

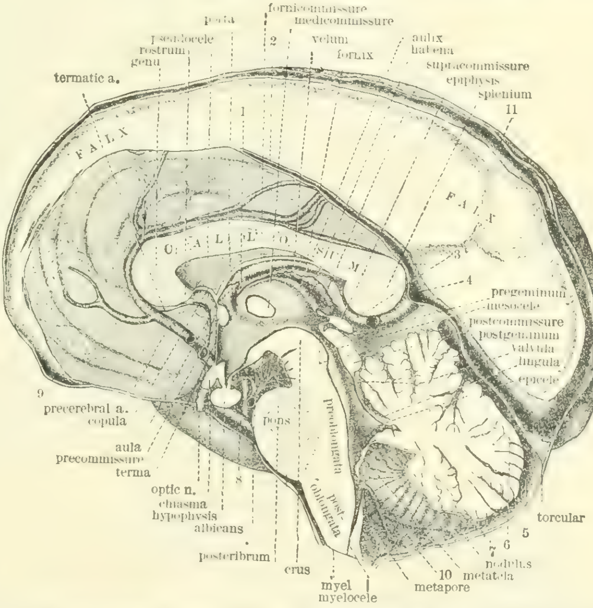

FIG. 801. Mesal Aspect of the Right Half of the Brain of an Adult White Man; 376. × .65. 1, Aulliplexus; 2, falcial sinus; 3, right velar vein; 4, orifice of Galen's vein into the tentorial sinus; 5, falcula or "cerebellar falx"; 6, tentorial sinus; 7, uvula, a mesal division of the cerebellum; 8, tuber ("tuber cinereum"); the line seems to stop at the artery, but should reach the thin floor of the diacele just caudad of the hypophysis; 9, ventral end of the falx; 10, cut edge of the ectal layer of the arachnoid, § 408; the line is too heavy and should be white instead of black; at a point between the lines from 6 and 7 it becomes attached to the cerebellar parachnoid; 11, longitudinal sinus.

Preparation. The brain was removed in the dura. It was duly supported and injected through the basilar artery with the starch mixture containing alcohol described in the article *Methods*, etc. The injection caused the brain to fill the dura completely, and presumably assume its natural form. It was then hardened in alcohol and medisected. The same specimen was the basis for two figures in my paper, 1885, *b*, and this figure is reproduced in the work of C. K. Mills, 1897; the mesal cavities are shown on a larger scale in Fig. 687.

Defects.—Although one of the purposes of the preparation of this figure was to indicate the relations of the dura to the brain, the word dura is omitted altogether. *Falx* designates its mesal extension between the halves of the cerebrum, as shown in Figs. 800 and 804. Along the longitudinal sinus (11) should be indicated the points of entrance of the supercerebral veins (see Fig. 800). The sinus, dorso-caudad of the cerebellum, between the torcular and the point marked 4, should be named *tentorial sinus*. On the precerebral artery, dorso-cephalad of the chiasma, are two orifices. The more caudal, at the root of the termatic artery, is caused by the removal of the left precerebral (see § 390, P). The more cephalic, between the lines from *copula* and *aula*, should be omitted, together with the intervening depressed area; they represent an accidental excavation of the artery. The arteries in the ventricisterna, the interval between the pons, the crura, and the tuber, are vaguely and inaccurately shown (see § 390, F). The postcerebellar artery (undesignated but lying between the lines from *metapore* and *metatela*) looks as if it begins in the metapore (see, however, § 390, H). The pia is nowhere distinctly represented. The black line marked 10 is the ectal layer of the arachnoid (see Fig. 806); the ental layer, in contact with the cerebellum, may be recognized; they unite just dorsad of the line from 7. The curved white line about midway between the callosum and the fornicommissure is due to an error; the surface of the hemiseptum forming the lateral wall of the pseudocele should be uniformly shaded. For other defects see Fig. 687.

Hirnhaut, weiche Hirnhaut; Fr., *pie-mère*). It is delicate, fibrous, highly vascular, and intimately connected with the neuron (central nervous system), into the substance of which it sends numerous nutrient small vessels. When stripped off, these vessels commonly break at a short distance from the pia, and their number and minuteness impart to the ental surface of the membrane a flocculent or woolly aspect, the *tomentum* (§ 376, E).

§ 392. *Myelic Pia.*—This is thicker and firmer than the encephalic, less vascular, and more closely adherent to the nervous substance. It has sometimes been called the "neurilemma of the cord." Two layers are recognized: the ental, sometimes called *intima pia,* sends a fold into the ventral ("anterior") fissure, and into the dorsal a lamina not recognizable as a fold. Along the ventri-meson the pia presents a conspicuous fibrous band, the *linea splendens,* not represented in Fig. 797.

§ 393. *Encephalic Pia.*—According to Shäfer (Quain, iii., 186), only the ental of the two myelic layers of the pia is represented on the brain, but where and how the other layer disappears is not stated. The pia follows all the undulations of the encephalic surfaces, dipping into the fissures and rimulas as folds or rugas of corresponding depth (see Fig. 796). At the bottom of the intercerebral fissure, the mesal cleft between the dorsal portions of the two hemicerebrums, the pia enters the callosal fissure at either side, is then reflected, and crosses the callosum *

§ 394. *Telas and Plexuses.*—For these structures of the pia see §§ 22–24.

§ 395. *Fig. 802 illustrates:* A. The different aspect of the cerebral surface (*a*) before the removal of the piarachnoid or leptomeninges, as in the cephalic (upper) third of the figure; (*b*) after it has been removed completely, as in most of the caudal two-thirds; and (*c*) when there remains the intrafissural fold, as in the left central and the part of the right central crossed by the line.

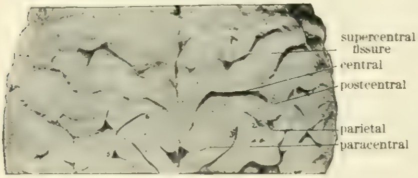

FIG. 802.—Central Region of an Adult Brain, Partly Denuded of Piarachnoid and Exhibiting on the Right a Departure from the More Common Relation of the Postcentral and Paracentral Fissures; 4,222. × .5. 1, The caudal end of a fissure which is mostly covered by the pia; 2, a small spur of the postcentral representing the usual caudal branch, which is marked 5 on the left; 3, an undetermined fissure; 4, a triangular depression comparable, perhaps, with the expansion of 5 on the left; 6, the cephalic branch of the left postcentral.

B. The usual relation of the central fissures to the paracentrals on both sides.

C. The usual relation of the left paracentral fissure to the dorsal fork of the postcentral (compare Fig. 769).

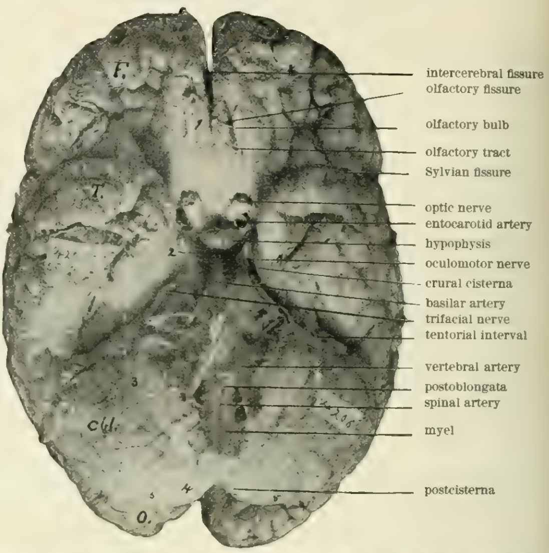

FIG. 803.—Base of the Brain of a Man Estimated at Sixty-Five Years, Before the Removal of the Piarachnoid and Blood-Vessels; 4,206. × .5. 1, Between the meson and the right olfactory bulb and opposite the point where the arachnoid ceases to pass directly from one hemicerebrum to the other and is carried into the intercerebral fissure by the falx (compare Figs. 801 and 804); 2, cut or torn margin of the arachnoid at the crural cisterna; 3, an artery on the right lateral lobe (pileum) of the cerebellum, *cbl.*; 5, 5, indicate approximately the lateral boundaries of the postcisterna (Fig. 807); *O.*, occipital lobe of the cerebrum; *T.*, temporal lobe; *F.*, frontal lobe.

D. The less common condition of the dorsal end of the right postcentral, the caudal branch being short and the cephalic so long as to intrude between the central and the paracentral and render that portion of the postcentral gyre quite narrow (§ 11, D; compare Fig. 664).

§ 396. *The Arachnoid.*—The word *arachnoid* is derived from the Greek ἀράχνη (signifying either a spider or a spider's web), and εἶδος (form or likeness).* In general the arachnoid may be described as a non-vascular membrane, enveloping the brain and closely attached to the pia, excepting where the latter dips into the intervals between the masses or into the fissures and sulci of the cerebrum and cerebellum. These depressions are bridged, so to speak, by the arachnoid, excepting where the dural folds, falx and falcula, carry it for a certain distance into the intercerebral fissure and the interval between the cerebrum and cerebellum. Wherever the arachnoid remains the outlines of parts are more or less vague, as in Figs. 796, 802, and 803.

§ 397. *Fig. 803 illustrates:* A. The general aspect of the base of the brain when first removed from the cranium; the outlines are less distinct than after the removal of the piarachnoid (compare Figs. 672 and 689), and certain features are wholly invisible, *e.g.*, the chiasma, precribrum, and crura.

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* Since the pia is practically the ectal surface of the brain, its cut edge is not commonly represented excepting when the figure is on a very large scale; but on blackboard diagrams its vascular character may be instructively indicated by a red line. On such diagrams the endyma ("ependyma" or lining of the cavities) may be represented by yellow or green.

* The open-meshed discs of the common garden spiders, *Epeira*, *Argiope*, etc., are not comparable; rather the compact glazed sheet constructed by one of the house spiders (*Tegenaria*) which will hold water, or the still more substantial nest of the water spider (*Argyronetra*), which is like a stationary diving-bell and retains the air placed under it against considerable pressure.

B. The varying relations of the arachnoid to the intervals between the masses. For nearly half of the distance between the optic nerves and the cephalic end of the cerebrum the arachnoid crosses directly from one frontal lobe to the other so that the intercerebral fissure is barely recognizable as a slight mesal depression. But at the point indicated by 1 the fold of dura constituting the falx (Figs. 801 and 804) begins and forces the arachnoid into the depths of the fissure. The arachnoid dips slightly into the Sylvian fissure, and deeply into the interval between the cerebrum and the cerebellum on account of the dural fold, tentorium (Fig. 800, 8).

C. The existence of a considerable interval, the crural ("peduncular") cisterna just caudad of the hypophysis, between the crura and adjacent brain surfaces and the arachnoid; the latter was torn and cut in removing the brain, and the sharp artificial margin is indicated by 2.

D. The existence of the postcisterna ("cisterna magna" or "cerebello-medullaris") between the oblongata and the cerebellum; by blowing dorsad at either side of the oblongata, where the arachnoid is torn, air entered the postcisterna and it expanded so as to have a convex outline as in Fig 807; but when the photograph was taken most of the air had escaped and the extent of the cisterna is indicated only by the greater vagueness of the cerebellar outline as far as 5 at either side.

§ 398. As to details, however, our knowledge of the arachnoid is even less complete and satisfactory than that of the dura and pia, and there are direct contradictions in the accounts by different anatomists which I have as yet been unable to reconcile. As stated by Langdon (1891), Bichat described (1802, 1813) the arachnoid as a serous, shut sack, conforming in all essential particulars with the serosa of the other cavities. But most recent writers follow Kölliker (1860) in denying the existence of a parietal layer in contact with the dura, and Tuke regards (1882) even the visceral layer as merely an element of the pia.

§ 399. On February 17th, 1888, I made and recorded the following observation upon a child, still-born, at term, No. 2,258: In removing the parietal dura, a delicate membrane separated from it more or less easily in different localities on the two sides; it was observed also by my colleague, Prof. S. H. Gage.*

§ 400. On December 29th, 1890, Dr. Langdon's paper (1891) was presented before the Association of American Anatomists. He records observations made upon two children, at term, and one adult. His summary is as follows:

"The arachnoid is a true shut sac, similar in structure and function to the serosa of the other great cavities. Its parietal layer is easily separable from the dura at the vertex in the fetus and young infant, but practically inseparable in this region in the adult. At the base of the skull it is demonstrable as a separate membrane, even in the adult. To assert that the parietal layer of arachnoid is absent because its subepithelial connective tissue has fused at the vertex with the dura (connective tissue), is as incorrect as to describe the great omentum as one layer of peritoneum, because its original four layers have become matted and adherent."

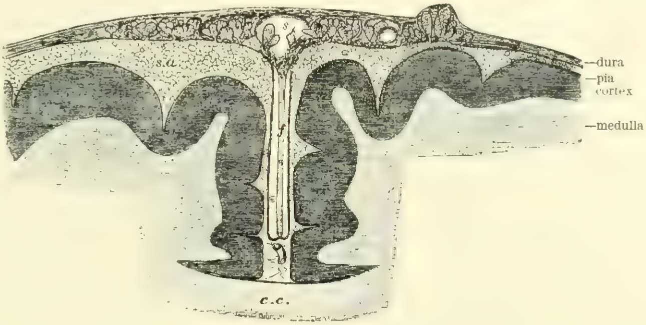

FIG. 804.—Transection of the Dorsal, Mesal Region of the Cerebrum, to Show the Meninges and Arachnoidal Villi. Slightly enlarged. (From Key and Retzius, Taf. xxix., Fig. 4; after Shafer: Quain, iii., Fig. 134.)

Preparation.—The spinal subarachnoid space (Fig. 797, *k*, *l*) was injected with a fine blue mass, which filled (and distended ?) the corresponding space upon the cerebrum and entered the arachnoid villi. The original figure is appropriately colored and on a larger scale. Judging from the relation between the width of the falx and the interval between it and the callosum, the plane of section was not far cephalad of the splenium (see Fig. 801). *c.c.*, Callosum; *f*, falx; *s*, longitudinal sinus; *s.a.* (at the left), subarachnoid space.

Defects.—The pia is not so distinct as I would make it. The relation of the arachnoid to the ventral margin of the falx is not quite clear. There is no extension of the cortical cinerea upon the dorsum of the callosum as an indusium (see § 217). There is no indication of the existence of the two layers of the dura, *e.g.*, periosteal and encephalic, described by Langdon (Fig. 798). The falcial (inferior longitudinal) sinus may have been absent in this case, as it is said to be in many. The *lacunæ laterales* are somewhat indistinct, probably in consequence of the reduction from the original figure, where they are much more clearly shown.

§ 401. During the preparation of the article *Meninges* in the first edition of the REFERENCE HANDBOOK I verified the correctness of the previous observation as to the presence of an ectal or dural layer of arachnoid, and noted its reflection upon the carotid and vertebral arteries to become continuous, presumably, with the ental, pial, or visceral layer. But no such reflection occurs at the nerve roots unless at some depth within the foramens of exit, and this point I have as yet not had time to determine.

§ 402. *Fig. 804 illustrates:* A. The relative positions of the meninges (compare Figs. 796 and 798).

B. The formation of the longitudinal sinus within the substance of the dura.

C. The projection of the arachnoid villi into the sinus and the parasinual spaces; see the article *Pacchionian Bodies.*

D. The accumulation of the villi at one point, on the right, to such an extent as to cause the protrusion of the dura, and presumably a depression of the ental surface of the cranium.

E. The separability of the arachnoid from the pia, leaving a distinct subarachnoid space increased along the fissure lines.

F. The conterminousness of the arachnoid and the falx, and their separation by a distinct interval.

§ 403. *Fig. 805 illustrates:* A. The complete circumscription of the true encephalic cavities, excepting at the metapore.

B. The non-communication of these cavities with the pseudocele (fifth ventricle).

C. The presence of considerable, irregular intervals, subarachnoid spaces, or cisternas, between the pia and the arachnoid.

D. The continuity of the largest of these, *postcisterna,* between the cerebellum, postoblongata, and occipital part of the cranium, with the spinal subarachnoid space.

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* Although this distinctly indicated the existence of a parietal (ectal) layer of arachnoid, at that time I supposed the subject, *Meninges*, would be treated by another, and was, moreover, then fully occupied with the articles already undertaken; hence the observation was not made public and the point has not been followed up.

E. The relation of the falcula (falx cerebelli) to the mesal portion, vermis, of the cerebellum. In Fig. 707 this is obscured by the fact that part of the left lateral lobe remains.

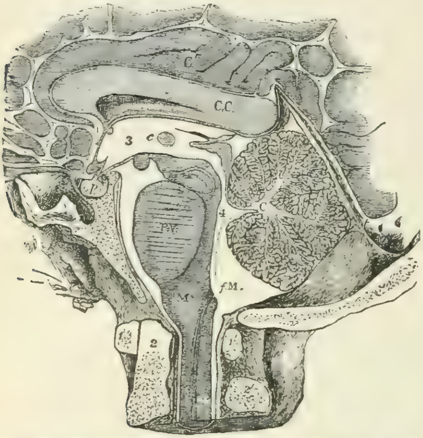

FIG. 805.—Medisection of the Cerebellum and Adjacent Parts. (From Key and Retzius, 1875, Taf. viii., vii., Fig. 1; after Shäfer: Quain, iii., Fig. 131, reduced and somewhat modified.) Compare Figs. 670, 800, and 801. 1, 1', Atlas vertebra; 2, 2', axis vertebra; 3, diacele (third ventricle); 4, epicele, the cephalic or cerebellar portion of the "fourth ventricle"; C, cerebellum; C.C., callosum; C', callosal gyrus; M, postoblongata; P.V., pons; X, falcula (falx cerebelli); c, medicommissure; c.c., just dorsad of (behind) the myelocele (central canal of the cord); f.M., metapore ("foramen of Magendie"); p, hypophysis; t, torcular.

Preparation. A blue mass was injected into the spinal subarachnoid space; the head was then frozen and medisected. The original includes the mesal aspect of the entire head, less the integument and mandible. The true encephalic cavities and the subarachnoid spaces are colored, so only the actual mesal parts appear.

Defects. In the original there is no indication of the arachnoid, although the circumscription of the subarachnoid space was the very feature supposed to be illustrated. Should it be claimed that the arachnoid is sufficiently indicated by the ental boundary line of the dura, the answer would be that, although in places the two meninges may be in contact, they are not in all; furthermore, as distinctly shown upon Taf. vi. of the same work, in Figs. 801, 806, and 807, there is a point near the crest of the cerebellum (nearly opposite t) where the arachnoid (or its ectal layer) leaves the cerebellum and passes directly to the dura at the *foramen magnum*. There is no boundary between the metepicele (fourth ventricle) and the subarachnoid space; even if, as in other cases, the membranous roof of the metacele (metatela) adheres to the caudo-ventral surface of the cerebellum, the plexuses and the endyma constituting its ental surface must end somewhere.

Since the cavities are not colored, they appear as white areas without perspective, as if the preparation were a thin mesal slice. Most unfortunately, probably through some defect in execution, there is left a clear line between the epiphysis and the splenium, as if there were a passage from the diacele (third ventricle) to the irregular subarachnoid space between the splenium, epiphysis, pregeminum, and cerebellum. This is altogether misleading, for, as shown in Figs. 670, 687, 759, and 801, and stated in § 66, H, the diacele is completely circumscribed at that point by the endyma reflected from the velum upon the epiphysis. In the present copy this defect has been remedied so far as it could be by uniting the epiphysis and splenium so as at least to block the passage; but it should be remembered that it is closed not by nervous tissue but membranes. The editors of Quain have represented the missing metatela by the dotted line from near the number 4 to near the abbreviation f.M. A continuous line would have been more appropriate, and separated farther from the metacelian floor; that could not be changed in the present copy, but the interval representing the metapore (foramen of Magendie) has been enlarged; this, however, is conventional, and as if to correspond with the perhaps unusual condition shown in Fig. 690. Finally, the falcula (falx cerebelli), which was unmarked in Quain, is here designated by a cross (x).

§ 404. *The Cisternas.*—At several regions the ental layer of arachnoid is separated from the pia by considerable spaces, called cisternas by Key and Retzius, 1875, p. 93.* They are enumerated and described by Browning.

§ 405. *Fig. 806 illustrates:* A. The general appearance of this aspect of the cerebellum together with the oblongata and pons; in Fig. 697 these two parts were omitted.

B. The extent of the postcisterna (*cisterna magna* or *c. cerebello-medullaris*) upon about one-half the entire caudal aspect; there is, however, considerable variation in this respect.

C. The definite dorsal and lateral limitation of the postcisterna, although the boundary line is undulating and asymmetrical.

D. The lack of ventral boundary of the cisterna; the ectal layer of the arachnoid is attached to the dura so that this cisterna is continuous with the spinal subarachnoid space.

E. The union of the two vertebral arteries to form the basilar.

F. The origin of the postcerebellar arteries from the vertebrals near their junction.

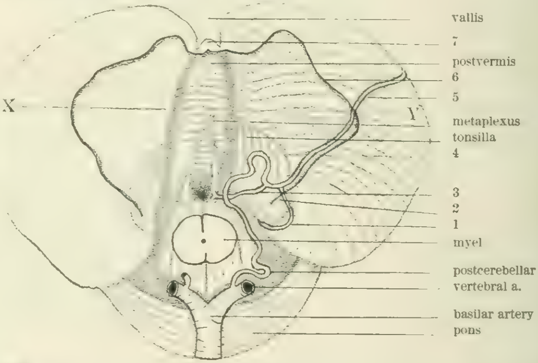

FIG. 806.—Caudal (Lower) Aspect of the Cerebellum, etc.; 376. × .9.

Preparation.—Through the kindness and skill of Dr. W. C. Krauss (a former student, now professor in the Medical Department of Niagara University, the brain was received fresh and in the dura. The cavities were injected with alcohol; the arteries first with alcohol and then with the starch mixture (see article *Brain: Methods*). The alcohol passed through the metapore into the postcisterna and thoroughly preserved all the parietes; it had access also about the myel, where the arachnoid was cut in removing the brain. The ectal layer of the arachnoid was cut away along the line of its attachment.

Defects.—The perspective of the postoblongata is defective. The metapore is vaguely indicated and few of the vessels are shown. Of the lobes only the tonsillas are outlined. The flocculi and nerve roots are omitted, also the rimulas (interfoliar crevices) on the left side. The most serious defect is the non-indication of the dorsal limit of the endyma which presumably accompanies the metaplexuses; see § 417.

1, 3, Branches of the postcerebellar artery, the former passing between the cerebellum and the oblongata, the latter apparently supplying the corresponding metaplexus; 2, 6, edge of the ectal layer of arachnoid bounding the area whence it had been cut away; 4, loop of postcerebellar artery, an example of its tortuous course; 5, main trunk of the artery near where it reaches the crest of the cerebellum; its branches are omitted; 7, mesal ridge formed by the vein which divides into a right and left branch upon the caudal surface; the arachnoid here forms a somewhat sharp angle.

G. The length and course of the postcerebellar artery, and the tortuous course of its central portion.

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* Admitting that most of the cisternas do lie between the arachnoid and the pia, as commonly described, my later observations lead me to regard the postcisterna as between two layers of the ental arachnoid itself (see Figs. 805 and 807).

H. The passage of a branch of the postcerebellar artery mesad toward the metapore, apparently supplying the metaplexus.

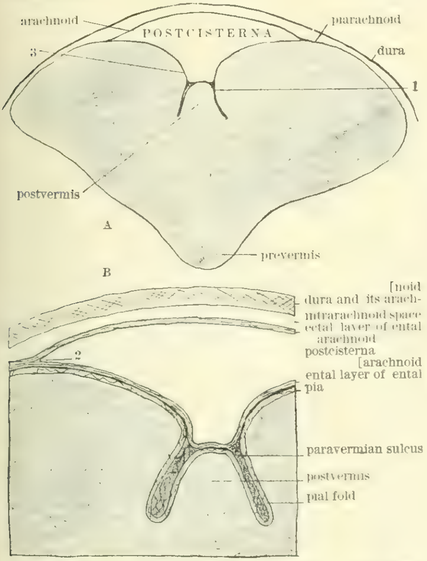

FIG. 807.—Sections of the Cerebellum and Postcisterna; semidiagrammatic.

A. Dorsal (cut) surface of the ventral portion of the cerebellum, together with the adjacent dura and the large "subarachnoid space," postcisterna, commonly called *cisterna magna* or *c. cerebello-medullaris*. At the meson appears the postvermis, separated by the paravermian sulci (1) from the large lateral lobes; 3 is the ental layer of the arachnoid. The meninges are here represented by lines only.

B. Enlargement of the meso-caudal region of A. The meninges are here represented by zones conventionally shaded; 2, the place of junction of the two layers of the ental arachnoid at the margin of the postcisterna.

Preparation. An adult cerebellum (2,891) was divided at a plane corresponding with the line X–Y in Fig. 806, so as to separate the dorsal two-fifths; on Fig. 801 the plane of section would be indicated approximately by a line across the unshaded (cut) surface connecting the points where the dotted lines from the words *nodulus* and *epicele* intersect the margin of that surface; as seen in Fig. 806 it passes dorsad of the plexuses. The ectal layer of arachnoid is represented as the continuous caudal boundary of the postcisterna, while in Fig. 806 it is supposed to have been trimmed closely along the line of its depression from the ental layer 3.

Defects. For readier comparison with Fig. 806 the figures should have been inverted so as to have the postcisterna nearer the reader. In B the postcisterna is enlarged two diameters, but the several zones representing the meninges are disproportionately widened, and their shading is conventional for discrimination only, and not for the indication of histological structure. The ectal or dural layer of arachnoid was inadvertently omitted, and there is no indication of the two layers of the dura itself. The numerous rimulas and intervening foliums that were divided in the section are not indicated, and the usual relations of the pia and arachnoid to each other and to narrow encephalic depressions generally are illustrated only at the paravermian sulci. According to the present view * that the metapore is the orifice of an evagination, the postcisterna may be lined, in part at least, by endyma; but it was not recognized in this preparation, and even in the embryo represented by Blake (1898, Fig. 26) it seems to have disappeared at a lower level.

I. The extension of the metaplexuses dorsad from the metapore upon the cerebellum.

§ 406. *Postcisterna.*—Notwithstanding the presumption that all the cisternas form a continuous series, my observations, up to the present time, induce me to regard the space in the angle between the cerebellum and the oblongata as presenting an important peculiarity, viz., as lying, not between the pia and the visceral arachnoid, but between two layers of the latter. The facts upon which this view is based cannot be detailed here. The view is indicated upon Fig. 807.

I am aware of the difficulties involved in its acceptance; without question, the postcisterna communicates on the one hand with the true encephalic cavities through the metapore, and on the other with the spinal subarachnoid space; its free communication with the other cisternas, although commonly accepted, seems to me not yet clearly demonstrated.

§ 407. *Is there Direct Communication of the Subarachnoid Spaces with the Intrarachnoid (or Subdural) Space?*—Whatever view they adopt regarding the constitution of the arachnoid as a whole, most writers agree that the arachnoid covering the brain and myel is continuous, excepting for the capillary spaces about the nerve roots referred to in § 401. Hence, while the neurolymph may pass to and fro between the true encephalic cavities and the postcisterna through the metapore, and may thus enter the other cisternas (§ 406) and the spinal subarachnoid space, it is nevertheless confined thereto.

But Dr. Langdon (1891) holds that "at the base of the cranium there are two points where the visceral [ental] arachnoid is deficient, one on either side, in the 'bridge' of arachnoid which stretches across from the cerebellar lobes to the under [ventral] surface on the oblongata. These foramina measure about half an inch (12 mm.) in longitudinal diameter by one-fourth inch (6 mm.) transversely, and are crossed by three or four fibrous bands, the attachment of which to the edges of the openings produces a multiple crescentic appearance of their margins, which suggests the name '*lunulate foramina.*'"

It will be noted that the location of these alleged lunulate foramina in the arachnoid corresponds with that of the ventral ends of the lateral recesses. Hence, on the one hand, if both are natural, the transfer of the neurolymph from the true encephalic cavities to the arachnoid space is provided for; on the other, the relation of the nerve roots to both the pia and the arachnoid renders both liable to rupture during extraction or manipulation of the brain. Hess implies (1885, Fig. 10, *ar.*) that the arachnoid was cut and reflected at this point. On the whole subject, and on the metapore see the later observations of Blake, 1900.

§ 408. *Fig. 807 illustrates:* A. The usual relation of the meninges in these respects, viz., the independence of the dura; the adhesion of the pia to the brain substance; the dipping of the pia into the narrow depression at either side of the vermis as a vascular fold; the adhesion of the arachnoid to the pia over most of the cerebellum, so as to constitute a piarachnoid (Fig. 796).

B. On the caudal aspect of the cerebellum, the formation of a considerable space, the postcisterna, by the separation of an ectal layer of the ental or visceral layer of the arachnoid.

§ 409. The inadequacy of the foregoing account of the postcisterna and its relations with the metapore is fully conceded. It is no disparagement to the labors of Blake and others to add that no account known to me is altogether clear, consistent, correct, and complete. The difficulties involved can be fully appreciated only by those who have already attempted to elucidate the subject. The material must be specially prepared for the purpose and examined by improved methods, both anatomical and histological. BURT G. WILDER.

§ 410. The following list includes treatises upon the gross anatomy of the brain, mostly recent, likewise a few special papers; other papers are named in the text. Other things being equal, preference is given to such as contain full bibliographies. The history of Neurology up to 1822 is given in Burdach. For current literature consult the *Journal of Comparative Neurology; Anatomischer Anzeiger; Index Medicus; Neurologisches Centralblatt; Brain; L'Encéphale; Névraxe; Jahresberichte*

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* At the time § 83 was made up into the page I was unaware that the German edition (1894) of Minot's "Embryology" has this passage, p. 698: "The foramen of Magendie (Wilder's metapore) and the openings of the lateral recesses, according to this view, would be not true perforations of the ependyma, but the outlets of evaginations."

für Anatomie, etc. See § 12. *A. A. A. Proc.* stands for *Proceedings of the Association of American Anatomists.*

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BRAIN, ABSCESS OF.—Cerebral abscess is always the result of the introduction of pus-producing germs into the tissues of the brain. The organisms which are found most frequently are streptococcus pyogenes and staphylococcus pyogenes aureus. Staphylococcus pyogenes albus and citreus are also found occasionally, but are always associated with the former ones. When the pus from the brain lesion has been compared with that from the primary wound or otorrhœa, the same organisms have frequently been found in both places. Bacillus pyogenes fœtidus has been found in one case in the abscess and in the discharge from the ear. Fraenkel's diplococcus pneumoniæ was obtained in a meningeal abscess which accompanied an abscess in the cerebellum. In one case the observer was unable to decide whether the germ was Eberth's bacillus entericus or Neumann's bacillus meningitidis purulentæ. In several cases pyogenic organisms were associated with Gessard's bacillus pyocyaneus. In two cases oïdium albicans was discovered; in one of these the brain contained small abscesses which were filled with the fungus.

Sabrazès reports a case of abscess of the centrum ovale, abscess of the apex of the right lung, anthracosis of the lungs and purulent softening of an infarction in the right kidney. The pus of the abscesses contained a micro-organism which was regarded as a streptothrix. It is probable that the lungs were the primary point of entrance of the germs. Ferré and Faguet also found a streptothrix in a cerebral abscess. Fraenkel obtained pure cultures of tubercle bacilli from the pus of a tuberculous abscess of the brain.

These various germs may be derived from any part of the body, but in the large majority of cases the primary lesion is located in the vicinity of the head and is due either to injury of the head or to ear disease.

When the disease is due to injury of the head the pyogenic organisms are sometimes introduced directly from the outer world. For example, in punctured wounds of the skull, the foreign body (splinter of wood, dagger, etc.) may be the direct carrier of the staphylococci and streptococci into the brain. Sometimes the skull itself is infected, then infection thrombi develop in the diploic vessels, and the bacilli pass along the perivascular sheaths to the brain. The infective injury to the skull may also be produced without fracture, if the outer table has been laid bare.

In the majority of cases due to injury the abscess is found in the vicinity of the injured part of the skull, but in exceptional instances it is found on the opposite side of the brain (contrecoup).

A similar pathological condition is presented by affections of the face and scalp, which may set up thrombosis of the veins and thus communicate with the brain.

Next in importance—perhaps even equal—to traumatic causes stand inflammations of the middle ear. The primary lesion is generally present from early childhood, as a sequel of one of the infectious diseases common to that period of life. It terminates in caries of the petrous portion of the temporal bone, attended usually with suppurative otitis media.

Caries in the tympanic cavity usually extends most markedly in certain directions. When it spreads through the antrum and involves the mastoid cells, some of which are adjacent to the sigmoid groove, the latter is apt to be involved and exposed. When the caries attacks the roof of the middle ear, perforation into the middle fossa of the skull frequently results. When the petrous portion is the site of extensive disease, suppurative leptomeningitis of the basal ganglia and cerebellum is apt to occur; even when the destruction is much less marked and the internal auditory meatus is exposed, the infective inflammation may pass along the sheaths of the facial and auditory nerves. In perforation of the tegmen, the abscess is situated in the temporo-sphenoidal lobe; in perforation into the sigmoid groove, the abscess is generally located in the cerebellum.

The mode of development of the abscess may vary considerably.

If the tegmen is involved the overlying dura mater becomes inflamed and adherent to the adjacent pia mater, and thus the veins and lymphatics of the latter are directly affected. The arterial vessels become thrombosed, and particles from the resulting emboli are carried with the pathogenic cocci to the interior of the temporo-sphenoidal lobe where they give rise to an abscess. As in cases of injury, the process may also creep along the perivascular sheaths.

When the perforation takes place into the sigmoid groove, the outer wall of the sinus undergoes inflammation; this extends through to the inner wall and thus induces thrombosis. The thrombus offers a nidus for the micrococci which pass along the cerebellar veins to the cerebellum. It must be remembered in this connection that the current of blood in the superficial veins may flow in either direction. The cerebellar arteries may also be thrombosed, and thus convey infected emboli to the interior of the cerebellum.

Cerebellar abscess may also be due to direct extension of the inflammation through the dura on either side of the sigmoid sinus.

In young children the infection often travels through the petroso-squamosal suture.

Cerebral abscess from ear disease is much rarer after acute suppurative otitis media than after the chronic form. In rare cases it follows tuberculous and syphilitic affections of the temporal bone.

Otitic abscesses occur generally in the temporo-sphenoidal lobe or the cerebellum on the same side as the aural lesion. In 119 cases collected by Koerner, 79 developed in the cerebrum and 40 in the cerebellum.

Infection from the nose and its appendages is much rarer. In a case reported by Dreyfuss, the infection, which started from suppuration of the antrum, was due to thrombophlebitis of the pterygopalatine and ophthalmic plexuses. In another case the process extended to the adjacent ethmoid cells and caused perforation of the lamina cribrosa. When the primary lesion affects the frontal sinuses, the posterior wall usually undergoes perforation or the infection takes place through the diploë. In very rare cases the primary infection is located in the orbit. In almost all of this group of cases the abscess is situated in the frontal lobes.

Embolic abscesses of the brain may be due to infection in any part of the body. They are observed particularly in association with pulmonary diseases (putrid bronchitis, empyema, gangrene, tuberculous cavities). They are less frequent after septic endocarditis, suppurative processes in the abdomen, joint and bone suppuration. They have also been seen after typhoid fever, scarlatina, diphtheria, glanders, and general pyæmia. Boettcher reports a case after pulmonary suppuration in which lung pigment was found in the brain. In two instances the abscess was due to the presence of oïdium albicans.

The category of so called idiopathic abscesses of the brain is being continually narrowed. Although the existence of such cases cannot be absolutely denied, still none should be pronounced idiopathic until careful search has been made unsuccessfully in all the organs for some possible source of infection.

PATHOLOGICAL ANATOMY.—An analysis of 458 cases collected by Le Fort and Lehmann showed that the abscess occurred in the cerebrum in 327 cases, in the cerebellum in 113 cases, in the cerebrum and cerebellum in 11 cases, in the pons Varolii in 5 cases, in the cerebral peduncle in 1 case, and in the fourth ventricle in 1 case.

According to Macewen 93 per cent. of traumatic abscesses and 87 per cent. of otitic abscesses are solitary. The majority of metastatic abscesses are multiple. Abscesses of the brain vary extremely in size. Some of the multiple abscesses occurring in the course of pyæmia or ulcerative endocarditis may be the size of a pea. Old chronic abscesses may occupy a large part of a cerebral hemisphere, or perhaps a considerable portion of the cerebellum.

Acute abscesses contain a thin pus, usually of a color varying from yellow to green, sometimes of a darker shade, from admixture with blood. Under the microscope this is found to contain pus corpuscles, drops of myelin, granular matter, and detritus of the nerve elements and the pathogenic micro-organisms. The walls of the abscess are usually irregular and jagged, and tear readily from the contact of the fingers. The cavity is irregular in shape at first, but at a later period it tends to become more rounded. For a varying distance around the cavity the brain substance may have a reddish, speckled appearance from enlargement of the blood-vessels and the presence of capillary hemorrhages. Still more externally the brain tissue is stained slightly yellow and softened from inflammatory œdema. The latter phenomenon is observed sometimes over a large area, and often appears to be the immediate cause of death. Sometimes the abscess ruptures into one of the lateral ventricles, and in rare cases the pus makes its way through the foramen of Monro into the opposite ventricle. In such cases death almost always occurs before ependymitis supervenes. Softening may extend to the ventricles and produce ependymitis even though perforation has not occurred. In other cases the abscess ruptures through the cortex (almost always at the convexity), and in this event, likewise, death may supervene before the development of meningeal inflammation. But in a large number of such cases meningitis occurs at the site of rupture and rapidly spreads over the entire meninges. Quite a number of cases have been reported in which the pus made its way through the original site of injury to the skull, through the external auditory meatus, through the sphenoid bones into the nasal cavity, or through the orbital plate into the orbit.

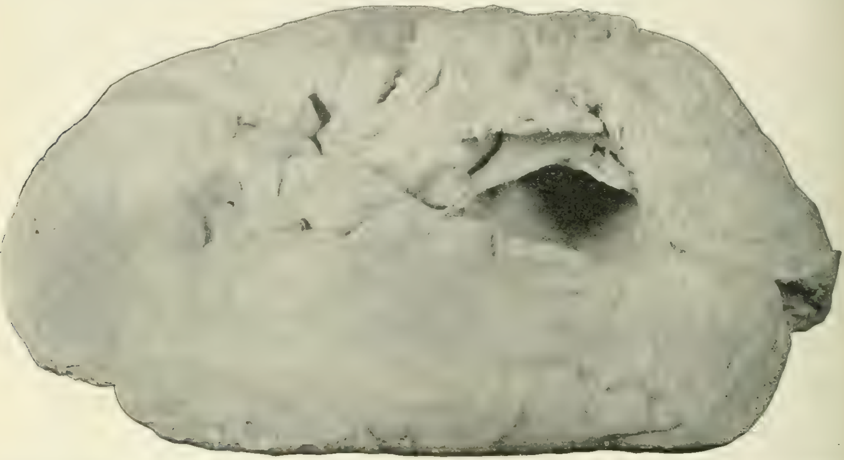
FIG. 808.—Abscess Cavity in the Brain. (Specimen in the collection of Prof. M. Allen Starr, M.D.; photograph taken by Dr. Edward Leaming.)

In the majority of cases the amount of healthy tissue between the cortex and abscess does not measure more than a few millimetres in thickness. In rare cases the abscess may be situated an inch or even more from the cortex. The abscess may be connected by a narrow fistulous tract with the meninges.

Chronic abscesses are usually round or ovoid in shape, and are provided generally with a connective-tissue membrane of variable thickness which lines the cavity. Rudolph Meyer states that about seven weeks usually elapse before the formation of a well-defined membrane. Lallemand found an abscess surrounded by a soft vascular membrane in a case which proved fatal thirteen days after the onset of the first symptoms. Huguenin found no membrane in an abscess which had lasted thirty-two days. Equally varying statements are made by other writers.

The membrane rarely insures a complete standstill of the process, inasmuch as it undergoes suppuration in places and this attacks the surrounding brain tissue. The new focus may again be surrounded by a fresh membrane.

The contents of the cavity are usually somewhat viscid, and consist of broken-down pus globules, drops of fat, cholesterin crystals, and granular matter. In a very few instances the contents have been found condensed to a thick, cheesy consistence, and in one case it is stated that earthy matter was present (calcification). When the abscess is of large size, fluctuation can usually be detected upon the convexity; the convolutions are flattened upon the side of the lesion, and sometimes the falx cerebri is pushed toward the opposite side of the brain.

When the abscess is situated in such a position (particularly the cerebellum) that the escape of fluid from the ventricles is interfered with, internal hydrocephalus may be the result.

The complications of cerebral abscess include suppurative meningitis, extradural suppuration, and thrombosis of the sinuses. All these conditions may also precede the development of the cerebral abscess.

According to Hessler, among 106 abscesses of the cerebrum 67 were uncomplicated, in 13 there was thrombosis of the sinuses, in 26 meningitis. Among 59 cerebellar abscesses 43 were uncomplicated, thrombosis of the sinuses was present in 10, and meningitis in 6 cases.

Macewen has reported a remarkable case of suppurative meningitis in the posterior fossa, while simple serous meningitis was found in other parts.

Widespread œdema of the brain is found not infrequently in cases of cerebral abscess, even in those provided with a thick membrane, and which do not appear to have given rise to much pressure. General cerebral anæmia is also observed quite often under such circumstances. The development of these sequelæ is still unexplained.

CLINICAL HISTORY.—The symptoms of an acute abscess of the brain after injury vary to a remarkable extent. Perhaps the immediate symptoms of the traumatism have been very slight; the scalp has been wounded, but the bones have escaped injury, and the patient is not supposed to be seriously injured. Or the patient has presented for a few days the signs of cerebral concussion, and then apparently recovers. For a variable length of time (from a week to two or three months) he continues in apparently good health, but then begins to complain of headache, dulness, and irritability. The headache is one of the most constant and earliest of all the general symptoms. It is rarely absent but varies greatly in intensity. It is especially severe during the growth of the abscess, and usually slight during the period of latency. It is sometimes felt over the entire head, but is generally more severe on the side of the abscess. In Koerner's twenty-one cases of cerebellar abscess, the pain was located in the occipital region only eight times. Pain in the back of the head is sometimes observed in frontal abscesses. Headache is often accompanied by rigidity of the back of the neck, particularly in abscesses of the posterior fossa.

In the majority of cases, according to Macewen, the temperature is normal or even subnormal during the entire course. When the symptoms begin suddenly fever may be present, but it is probable that the febrile movement is partly due, in many cases, to the primary disease or to complications.

As a rule, the pulse is slow at the height of the disease. Toynbee and Wreden described cases in which it fell to 10–16 per minute. The slowness of the pulse may persist during an increase of the bodily temperature.

After a while the headache increases in severity, and the patient may be confined to bed on account of the general malaise. The irritability and excitement likewise increase, delirium supervenes, and epileptiform convulsions may make their appearance.

Then the delirium changes into hebetude, somnolence, and coma; the pulse becomes rapid and irregular. Death either ensues rapidly or recovery slowly occurs, and the patient is restored apparently to health, with the exception, perhaps, of a monoplegia or hemiplegia, or even without any local symptoms. He then enters upon the so-called latent stage. The symptoms described are very like those of acute meningitis, and, indeed, this lesion may be associated with the encephalitis from the beginning, or it may develop secondarily.

Sometimes the symptoms begin with great suddenness, and at once assume an alarming aspect.

In another series of cases the symptoms of concussion or compression of the brain, due to the original injury, continue without intermission or improvement, and are rapidly merged into those due to the developing encephalitis and abscess formation, so that it is impossible to tell when the one process ends and the other begins. Such cases usually run a more rapid course than the former variety.

Finally, not a few cases have been reported in which the abscess has remained entirely latent for a long period, without giving the least indication of its presence. In fact, the autopsy alone may reveal the existence of a hitherto unsuspected chronic abscess. In a case observed by Nauwerk, the period of latency lasted twenty-eight years.

Sometimes the sole symptom of the so-called latent stage has been the occurrence of epileptiform convulsions, so that the case has been regarded as one of ordinary epilepsy. In other cases, chills, followed by a hot stage and sweating, occur at irregular, or, in rare cases, perfectly regular intervals, so that a diagnosis of intermittent fever has been made. An instance of this kind has come under my own observation. Usually, however, such patients also suffer from violent headache, frequently localized in the vicinity of the abscess.

Abscesses of the frontal lobe are more apt than others to be unattended with symptoms during the stage of latency. In a case of this kind, observed by me in the person of a lunatic, the mental condition seemed to be somewhat improved during the period of latency (one month). The night before her death, she had what were supposed to be hysterical convulsions (irregular twisting movements without loss of consciousness), as the patient had exhibited other hysterical symptoms for a year (the injury which gave rise to the abscess was received a month before the onset of the convulsive seizures). On the following morning the patient was found dead in bed. The autopsy showed an abscess of the frontal lobe, which had burst (evidently shortly before death) through the convexity.

The clinical history of otitic abscess of the brain is modified by the symptomatology of the primary disease of the ear. The initial symptoms usually consist of pain in the ear, vomiting, vertigo, tinnitus, and rise of bodily temperature. Inasmuch as all these symptoms may be the result of simple retention of pus in the diseased ear, it may be impossible to determine for some time whether the brain has really become involved. The condition is still further obscured by the fact that in these cases we observe frequent complications with purulent meningitis, pachymeningitis, and thrombosis of the sinuses.

In the majority of cases the abscess runs an acute or subacute course.

Mental obtuseness generally becomes noticeable soon after the onset of the disease. The patient answers questions correctly but slowly, and, when the eyes are open, stares into vacancy. The somnolence may deepen quite rapidly into coma.

When the disease runs a chronic course, the history is essentially the same as that of the traumatic variety.

On account of their embolic origin metastatic abscesses usually develop suddenly. In the majority of cases the emboli enter the middle cerebral artery and are carried to terminal branches, so that we generally find evidences of an affection of the motor region of the brain. Pure Jacksonian epilepsy is not an uncommon feature of these cases. Paralytic symptoms are much more frequent. Various aphasic disturbances have also been observed. In a considerable proportion of cases the abscesses are multiple and the focal symptoms are thus obscured.

The brain symptoms are often associated with evidences of general infection, viz., fever, chills and sweats, and rapidly developing cachexia.

It is unnecessary to say that, if the abscess is situated in such a position that it either involves the cortex in some part which presides over a special function, or destroys the white matter in such a manner as to cut across the fibres leading to such portions of the cortex, the corresponding symptoms will be produced. Thus, hemianopsia, aphasia, word-deafness, paralysis of individual nerves (very rarely), monoplegia, or hemiplegia may be produced in this manner. As occurs likewise in the clinical history of tumors of the brain, hemiplegia results usually from a succession of monoplegias, due evidently to a gradual spread of the destructive process from one set of fibres to another. This fact may be of invaluable service in making a regional diagnosis.

But, unlike tumors of the brain, cerebral abscesses rarely give rise to paralysis of cerebral nerves. Choked disc is also much less frequent and less marked than in tumors. According to Oppenheim, choked disc is much less frequent than optic neuritis. The affection of the optic nerve is sometimes confined to one eye. In operative cases the optic disturbances may disappear gradually after the operation.

The frequent absence of choked disc may be accounted for, perhaps, by the fact that the encephalitis spreads by causing adjacent parts of the brain to become directly involved in the inflammatory process, and in this way less pressure is produced upon adjacent parts.

In a certain proportion of cases all "head symptoms" are entirely wanting during the so-called latent stage, and we are sometimes astounded at the autopsy at discovering the great apparent disproportion between the amount of brain tissue destroyed and the slight character of the symptoms which had been produced. This is especially striking if we compare the symptoms with those which usually result from cerebral hemorrhages, even when much smaller in size. It must be remembered, however, that the latter lesion is usually situated in such a position (internal capsule and surrounding parts) that comparatively slight destruction of tissue interferes materially with the conduction of nervous impulses.

Vomiting is a not infrequent symptom, and may occur when the stomach is either full or empty.

In certain rare cases, the sole symptoms observed during the period of latency are those of mental derangement, and the patient is supposed to suffer from insanity as the result of injury to the head. In a case recently under our observation, such an error in diagnosis was made by a very eminent neurologist, and the true nature of the case was revealed only at the autopsy, as the psychical symptoms persisted, uncomplicated with any other manifestations, until the terminal meningitis set in.

As a general thing, the latent period is brought to a close by a sudden irruption of symptoms, beginning either with an epileptiform convulsion or a series of convulsions, with great exacerbation of the headache, mental irritability and delirium, or with sudden coma. The symptoms which follow are very similar in character to those which we have described above as occurring in acute abscess. After a short period (varying usually from a few hours to several days), the symptoms either terminate fatally (this is the rule) or they gradually clear up. But sooner or later, after another period of latency, in which the symptoms are more violent than in the first period, a second outburst occurs, which terminates fatally.

From the reports of a few isolated cases it seems probable that chronic abscesses may undergo spontaneous recovery, inasmuch as the pus becomes cheesy or even calcareous. But such an event, if it happens at all, must be extremely rare.

Diagnosis.—In making a diagnosis of abscess of the brain great importance attaches to etiological considerations. We are rarely justified in making the diagnosis unless we obtain a history of a previous injury to the head, of a purulent disease of the ear, nose, or other adjacent parts, or of some source of infectious emboli in distant parts of the body, notably in the lungs.

Injury to the head is followed, in rare cases, by tumor of the brain. But in such cases it will usually be found that the primary wound was not infectious in character, and, moreover, the symptoms follow one another in a steadily progressive manner. Furthermore, choked disc is much more constant and pronounced in tumor cerebri, while the subnormal temperature, or the fever and chills of abscess are wanting.

Injury to the head may also give rise to other symptoms which simulate abscess of the brain but which are in reality due to hemorrhagic encephalitis. In the latter affection the symptoms begin suddenly. They may terminate in complete recovery or rapid death, or the majority of the symptoms may disappear and leave permanent focal symptoms.

In considering suppurative disease of the middle ear as a factor in the diagnosis of cerebral abscess, it should not be forgotten that severe cerebral symptoms may be produced by the mere retention of pus in otitis media independently of the existence of cerebral lesions. A number of cases have also been reported in which optic neuritis or choked disc was associated with simple otitis media. This peculiar combination has been explained in various ways, viz., as the result of thrombosis of the sinuses, of infection of the carotid canal and extension along its lymph channels to the sheath of the optic nerve, and of serous meningitis.

Extra-dural abscess often cannot be distinguished from cerebral abscess; indeed, in many cases the two lesions are combined. According to Jansen, extra-dural abscesses exhibit the following characteristic features: (*a*) thickening of the bone, subperiosteal abscess or œdematous swelling behind the mastoid process; (*b*) pain on pressure and percussion in this region; (*c*) impaired mobility of the head, particularly around the sagittal axis; (*d*) nystagmus of both eyes, on voluntary motion, chiefly toward the side of the healthy ear.

Otitic thrombosis of the sinuses is also difficult of differentiation. In the majority of cases there is considerable intermittent fever, and the pulse is irregular and rapid. Many cases are attended with chills, sweats, and profuse diarrhœa. In some cases all these symptoms may be wanting. In thrombosis of the cavernous sinus we find œdema of the eyelids and surrounding parts, and protrusion of the eyeball. In thrombosis of the transverse sinus, certain symptoms may be due to implication of the upper part of the jugular vein. This vein is tender on pressure and may be felt occasionally as a hard cord. Small abscesses may develop in surrounding parts. Œdema behind the mastoid process is very frequent.

Focal symptoms are usually wanting in thrombosis of the sinuses.

When abscess and thrombosis are combined the condition becomes still more difficult of diagnosis.

It is also difficult in many cases to differentiate meningitis from abscess. The former disease usually runs a more rapid course than abscess, is attended with considerable fever and acceleration of the pulse, general convulsions are frequent, and there is also hyperæsthesia of the entire skin in many cases. Rigidity of the neck is a common symptom, together with retraction of the abdomen and increase of the tendon reflexes. In children all these symptoms are sometimes produced by retention of pus in the middle ear and may be relieved by evacuation of the pus.

The regional diagnosis must be made according to the principles laid down in the articles on *Diagnosis of Local Lesions* and on *Functions of the Cerebral Cortex* (both in the present series of brain articles).

Prognosis.—The prognosis of this affection has been modified very materially in the last fifteen years by the progress in antiseptic surgery. Spontaneous recovery by caseation or calcification of the abscess or by rupture externally is extremely rare. But operative interference now promises a good measure of success. Oppenheim found that in 53 cases of operation upon traumatic cerebral abscess 36 terminated in recovery. Koerner collated 92 operative cases of otitic cerebral abscesses; 51 cases recovered and death occurred in 41 cases. Macewen's results were remarkably favorable. Among his 25 cases of cerebral abscess he operated upon 19, and of these 18 recovered.

The poorest chances of successful surgical interference are presented by metastatic abscesses in which there is general pyæmic infection. Complication with thrombosis of the sinuses or meningitis also makes the prognosis more unfavorable.

Treatment.—Medical treatment of this affection, apart from meeting the individual symptoms as they arise, is utterly useless, as we possess no remedy which will cause the absorption of the pus after it has once formed.

Prophylactic measures are useful, perhaps, in preventing encephalitis after injuries to the head. The chief measures are absolute mental and bodily rest (the patient kept on his back, not allowed to sit up, to read, or to talk with those around him), which should be continued, if the injury has been violent enough to produce unconsciousness, for at least a week or two after the subsidence of the cerebral symptoms. In addition, the bowels should be kept thoroughly open by some mild saline, or by small doses of calomel.

Prophylaxis may also prove of benefit in diseases of the ear and nose. Free vent to the pus should always be secured, and paracentesis performed as soon as retention of pus develops.

As soon as the diagnosis is assured, operative interference is indicated. In some cases this has proved successful, even when the patient was in a moribund condition or a complication with purulent meningitis had developed. In some instances repeated operations have been necessary, either because the abscess refilled or because fresh abscesses developed in the immediate vicinity of the primary one. *Leopold Putzel.*

BRAIN, ANÆMIA OF.—Anæmia is a condition and not a disease in the proper sense of the term. Moreover, it is a condition which rarely or never exists uncomplicated. The causes which produce it are very apt to produce independently irritation and inflammation, or the same conditions which at first bring about an anæmia of the brain may, if their action be longer continued, excite in its place a cerebral hyperæmia. In the present state of our knowledge it is, moreover, often impossible for us to prove whether certain symptoms are really produced by an anæmia or by a hyperæmia of the brain, and in such cases we are forced to come to a decision on very imperfect grounds.

Of the fact that the anæmia in itself acts as an irritant on the nerve centres there can be no doubt, but its chief effect on them is produced through the deprivation of nutrition which it causes. In considering anæmia of the brain, it is not possible for us to differentiate the symptoms caused by deprivation of nutrition to the cerebral tissues through loss of blood and those caused by deprivation of nutrition to the same parts on account of the poverty of the blood in nutritive material suited to their needs. Hence the term cerebral anæmia has come to denote not only that condition in which there is an absolute diminution of the amount of blood in the brain, but also all those, so long as no toxic element is involved, in which the blood supplied to the brain is, from its composition, incapable of affording due and sufficient nourishment to the tissues. As a change in the condition of the blood is in most cases concurrent with a diminution in its amount, we may fairly say that cerebral anæmia, when universal, is usually "a complex condition, depending not merely upon a deficiency of the quantity of blood supplied to the brain, but also upon a change in its quality, and upon a diminution in the intracranial pressure" (Ross, ii., 611).

Anæmia of the brain may be either universal or partial, according as the whole or a portion only of the organ is involved. Partial anæmia, except when caused by occlusion of a blood-vessel through pressure, thrombosis, or embolism, is rare, and its symptoms are often not recognizable during life.

We shall hence consider here only universal cerebral anæmia. This may be either acute or chronic, and it may be due to a condition confined to the brain alone or may form part of a general anæmia.

Acute universal anæmia of the brain is always the result of the sudden withdrawal of a large quantity of blood from that organ. It occurs typically in ligature of the large arteries in the neck, the innominate, the carotids, or the vertebrals. These operations are performed usually either on account of injury, or for some tumor or aneurism. The vertebrals were formerly sometimes tied as a cure for epilepsy.

1. The most common cause of acute cerebral anæmia is, however, undoubtedly hemorrhage. This may occur from any part of the body, provided only that sufficient blood be lost with sufficient rapidity. Putting aside hemorrhages due to injuries, the more common forms are metrorrhagia, especially post partum, epistaxis, hæmoptysis, and hemorrhages from the stomach and intestines; occasionally also the rupture of aneurisms.

In cases of hemorrhage from injury the influence of shock must always be taken into account, as there are few cases of severe injury in which it does not exist to a greater or less degree. The pathological condition existent in shock is as yet unknown. One hypothesis is that maintained by Gröningen, that the complex of symptoms known by this name is due to an exhaustion of the medulla oblongata and of the spinal cord, produced by violent and severe drains upon their strength. Other writers consider shock as due to sudden changes in the calibre of the blood-vessels. Thus it is defined by Fischer as a reflex paralysis of the vaso-motor nerves, especially of the splanchnic, produced through a traumatic concussion. However this may be, cerebral anæmia is certainly produced by shock, and, as Travers says of shock and fainting: "They differ in degree and duration more than in kind."

2. Acute cerebral anæmia may be produced by any sudden change in the distribution of the blood in the body at large. Any cause which suddenly attracts a large quantity of blood to one portion of the body will naturally reduce the amount which can go to the other parts, and hence will induce an anæmia in them. This sudden change in the general distribution of blood in the body is said to occur after violent labor, when, the uterine vessels being suddenly released from pressure, large quantities of blood enter them freely and are thus withdrawn from the rest of the body. To this cause are probably in part also due the serious symptoms which sometimes occur after the withdrawal of large quantities of fluid from the pleural or peritoneal cavities. Another example of this form of disturbance is given in the action of Junod's boot, which, if carelessly used, may provoke dangerous symptoms.

3. A third cause of this form of anæmia is want of energy in the action of the heart. This is a common cause of chronic anæmia, but the acute form may readily be produced by any sudden demand for increased exertion on the already weakened heart. This is readily seen in anæmic persons and those suffering from insufficient action of the heart, in their liability to faint on any slight exertion, or even on rapid change of position. More especially is this the case in convalescents from acute febrile diseases, and it is particularly apt to occur after acute pneumonia. This frequently takes place when the patient rises suddenly from the horizontal position, the change in the distribution of the blood, which under normal circumstances would not be perceived, making itself felt.

In organic diseases of the heart cerebral anæmia in the acute form frequently occurs, more especially in aortic regurgitation, in which death from syncope is not uncommon. Persons suffering from myocarditis or from fatty degeneration of the heart are likewise peculiarly liable to attacks of fainting.

Anæmia of the brain may in like manner be produced by irritation of the vagus nerve through its action on the heart. Brown-Séquard and others have found that crushing of the right semilunar ganglion causes stoppage of the heart, and the deaths which sometimes occur from syncope in nervous and delicate persons, who are suffering from hepatic colic, may perhaps be referred to some similar cause. We may also mention here, though without any special reference to the method of their causation, those cases of syncope and collapse which occur in perforation of the stomach or intestines, and in which death is not infrequent. Hill believes that "the cerebral circulation is controlled by the vaso-motor centre acting on the splanchnic area."

That intestinal disturbances even of a light character are especially liable to produce syncope is well known. Even a transient abdominal pain or a slight attack of intestinal colic frequently causes the symptoms of faintness or even actual syncope. Syncopal cardialgia and a tendency to faint are said to be especially common in those suffering from the dyspepsia of gout.

4. Again, a diminution of the amount of blood in the brain sufficient to produce the symptoms of cerebral anæmia might be caused through the spasmodic contraction of the cerebral arteries. This is supposed to occur, when, from emotion or mental excitement, there is pallor of the countenance, and even loss of consciousness, without any failure of the action of the heart. The not uncommon occurrence of fainting at the sight of surgical operations, or at the sight of blood, would come under this head. Syncope, and even sudden death, may be caused by the sudden advent of any strong emotion—surprise, terror, grief, or joy. How far shock or the irritation of the vagus comes into play in these cases is yet undecided.

Nothnagel considers it possible that in attacks of epilepsy we have to deal with a spasmodic contraction of the cerebral blood-vessels, due to the irritation of a cerebral vaso-motor centre; but this cannot in the present state of our knowledge be considered as proved. Hill states that there is no evidence of the causation of cerebral anæmia by spasm of the cerebral arterioles.

The occurrence of vaso-motor nerves on the vessels of the pia seems probable according to the latest investigations (Obersteiner, Hill).

Hill states that "in every experimental condition the cerebral circulation passively follows the changes in the general arterial and venous pressures."

That cerebral anæmia may also be excited by irritation or stimulation of the sensitive nerves is well known. Intense pain may produce faintness or even syncope, but the exact method of action by which this effect is brought about must still be considered undecided. Nothnagel's and Krauspe's experiments on the sciatic and crural nerves do not appear conclusive, more especially in the face of the conflicting results obtained by Riegel. Ross states that these symptoms "may result from reflex irritation of the vagus or direct irritation of the sympathetic. But the direct effect produced on the nerve centres must also contribute to the result." Nothnagel considers the cerebral anæmia caused by catheterization to be likewise due to irritation of the vaso-motor centres.

5. Cerebral anæmia may in like manner be produced by the sudden introduction of foreign substances into the cavity of the cranium, thus inducing compression of the blood-vessels. The most common cause of this is an effusion of blood; but in cerebral or meningeal hemorrhage the pathological condition is a complex one, and it does not properly come within the limits of this article.

6. It is probable that acute universal anæmia of the brain may be induced by certain poisons, but direct proof in this regard is still wanting.

Chronic universal anæmia of the brain may be produced not only by all the causes mentioned above, provided that their action be gradual and continued for a sufficient length of time, but also by all conditions of the system in which the amount of blood as a whole is much lessened or its active power much diminished. Hence in all cases of general anæmia and chlorosis we find a corresponding anæmia of the brain. This is especially apt to occur after long and wasting diseases, such as phthisis pulmonum, Pott's disease, or long-continued suppuration in any form. More particularly is this the case whenever large quantities of fluid of any sort are steadily withdrawn from the body for any length of time, as in chronic diarrhœa. Hyperlactation is a not infrequent cause. Nothnagel, moreover, considers that many of the symptoms occurring in cases of starvation are directly referable to cerebral anæmia, although in these cases there probably always exists a greater or less amount of cerebral irritation.

Anæmia of the brain and meninges is specially apt to occur in the convalescent stage of acute febrile diseases, "the late cerebral anæmia of severe fevers" of Jaccoud, who considers, however, that this is not a simple anæmia but an anæmia with dyscrasia.

Affections of the heart, moreover, are not uncommon factors in the etiology of chronic anæmia. Whenever there exists a weakness of the cardiac action, whether due to functional causes or to organic lesions, we may suspect anæmia of the brain. This is probably always present to a greater or less extent in cases of fatty degeneration of the cardiac walls and in most cases of uncompensated valvular disease. It is most frequent in insufficiency of the aortic valve.

How far chronic anæmia may be brought about by the presence of extraneous substances in the cranial cavity is an open question. The presence of inflammatory exudations, transudations, or tumors is supposed at times to cause an anæmia by pressure, but in many cases an irritative process seems to preponderate and a hyperæmia exists.

Partial or circumscribed anæmia of the brain is caused by the diminution of the calibre of the blood-vessels supplying a portion of the brain, or by their occlusion. Unilateral anæmia is produced by ligature of the carotid. In many cases it is but temporary, and the symptoms soon disappear, but in others they are said to remain and become more or less permanent. This depends, at least in part, on the condition of the communicating arteries of the circle of Willis, irregularities in which were found by Ehrmann in from nineteen to twenty per cent. of the bodies taken at random and examined by him.

The commonest cause of partial anæmia in the brain is thrombosis, or embolism, by which a blood-vessel is partially or wholly occluded. The presence of tumors or exudations may likewise cause a partial anæmia by pressure exerted over a vascular area, or on a special blood-vessel. How far local spasm of the cerebral blood-vessels may cause circumscribed anæmia is still doubtful. Nothnagel states that it may occur in hemicrania and in the petit mal (epilepsy). Eulenburg says: "The group of symptoms called hemicrania sympathico-tonica is to be explained by supposing a unilateral tonic spasm of the vessels of the head caused by tetanus in the cervical region of the sympathetic, or in the spinal centre of the cervical sympathetic."

SYMPTOMATOLOGY.—Experiments made on compression of the carotids in healthy male adults show that the following effects are produced. In the first place, there is pallor of the countenance, then convulsive efforts to close the eyes are seen, with contraction, to be followed later by dilatation of the pupils, a sighing respiration, dizziness, staggering, and finally unconsciousness. A sensation of choking may occur, and sometimes vomiting and general convulsions. How far these symptoms may depend on the anæmia pure and simple, and how far they may be due to other causes, we cannot consider here. In the present condition of our knowledge it is not possible to determine with absolute certainty, in regard to many of the symptoms which are present in conjunction with anæmia, as to whether they are due to the anæmia itself or to various concomitant conditions; while, on the other hand, there are many conditions in which the symptoms generally ascribed to anæmia are present, and in which the condition and circumstances of the general body would point most strongly to an anæmia of the brain, and yet in which, on post-mortem examination, the actual state of the cerebrum would seem to be rather hyperæmic than anæmic. Thus Flemming, in the "Pathologie und Therapie der Psychosen," says: "The fluctuations in the quantitative relations of nutrition in the brain vary between the extremes of lack and of excess of blood, anæmia and hyperæmia. Under circumstances which, as well from the precedent injuries as from the whole behavior of the organism, would lead us to conclude, in so disproportionate a blood supply (oligæmia), that even the brain could not readily be provided with its normal needs, we still see the psychical functions altered in a manner which points far more to an increased supply of blood. The autopsy also, in such cases, shows the opposite of what we should expect from the general oligæmic condition of the body. It shows the brain throughout, or partially, on its surface, or in its internal portions, reddened by the blood seen through the tissues, while the cut surface is dotted with numerous bloody points and the vessels are distended with blood. In short, there where we expected anæmia it shows far more a hyperæmic condition."

Hence, in describing the symptoms which are usually referred to anæmia of the brain, we desire that these facts be constantly borne in mind, that in many cases symptoms have been ascribed to anæmia which were in all probability due to other conditions of the brain, and even when the anæmia coexists there is in a large proportion of cases no proof that the symptoms are due to it alone.

In acute anæmia of the brain we have a series of symptoms extending all the way from general weakness to profound insensibility, and which are known according to their intensity by the names *eclysis*, *lipothymia*, and *syncope*. All these are apt to be classed together under the name of fainting fit. These symptoms are subjectively usually as follows: A person about to faint usually notices first a slight oppression in the breathing, and a sensation of lightness in the head. He is often inclined to gape, and finds difficulty in fixing or concentrating his attention. Gradually the respiration becomes deeper and more labored, and a feeling of nausea and weight in the epigastrium comes on. At the same time his face becomes paler and paler, and he becomes more and more dizzy, until he finds it difficult to maintain his equilibrium. His head feels tense and his ears begin to ring, a mist comes over his eyes, and at times he is scarcely able to see, though still able to stagger toward the fresh air. He is often nauseated, and perhaps vomits. Surrounding voices can be heard but not distinguished, and, unless relieved, he becomes insensible and falls without a cry to the ground. If now left to himself he generally soon recovers, but recovery can be readily hastened by the presence of fresh air, or by gentle stimulation of the olfactory nerves. Objectively, the principal symptoms noticeable are, in the first place, the extreme pallor of the face, especially marked on the mucous membrane of the lips, the gaping and deepened respiration, then the staggering or loss of control over the equilibrium. The pupils contract at first and then dilate, and the pulse becomes small and its tension is diminished. The skin is pale and cold, and a cold perspiration breaks out over the forehead and sometimes over the entire body. This stage ends in the abolition of consciousness and of voluntary movement.

These are the usual symptoms in a slight attack of fainting coming on gradually from exposure to heat and close air, or from mental emotion. When the fainting, however, comes on rapidly, the prodromal symptoms may not appear, but the patient turns pale and falls insensible almost immediately. In severe cases, in addition to the previous symptoms, we may have Jacksonian epilepsy or generalized convulsions, sometimes extremely violent, and resembling in all respects epileptic convulsions. These are liable to occur in all cases of sudden and profuse hemorrhage in previously strong and healthy individuals.

When the anæmic condition is produced more slowly, either from long-continued undernutrition of the body or as the result of a severe physical strain, as a serious fever or other acute illness, the symptoms present themselves in a somewhat different form. In children, after any severe strain on the physical forces, and particularly after intestinal diseases, in which a considerable amount of fluid is rapidly withdrawn from the tissues, we meet with the so-called *hydrencephaloid* disease, for our knowledge of which we are still principally indebted to its first describer, Marshall Hall, who "first gave a cursory sketch of this morbid affection in a little volume of 'Medical Essays' published in 1825." He there says: "The state of exhaustion is very apt to be induced in *early infancy*, and as the reaction is feeble at this period of life, the case soon assumes the character of sinking. This state of things is often mistaken for inflammation of the brain or hydrencephalus."

In adults as in children, chronic universal anæmia of the brain is liable to be characterized by a condition of abnormal stimulation, both mental and physical. In both there is the same restlessness, uneasy sleep, and intolerance of light and sound; while in adults the mental irritability is probably more prominent only because it is more readily shown. In the severer forms, and more particularly in cases of starvation, delirium, the "delirium of inanition," is liable to occur. This is usually active and frequently maniacal in character, and is accompanied by hallucinations, illusions of sight and hearing, and not infrequently by delusions of persecution. Nothnagel states that there is almost always an undertone of sadness, and that hence the symptoms as a whole belong to the type named melancholia agitans. It is said that occasionally this may pass into permanent insanity. In regard to the delirium of starvation, Longet writes as follows: "There is some consolation for us, after considering the pathological conditions in which hunger presents itself, with the character of inexorable irresistible force, in turning to the analogous phenomena which are produced in the healthy individual when deprived of food. We are compelled to believe that under these circumstances there supervenes a pathological state; a peculiar delirium, that of hunger, the delirium of starvation appears; were it not so, we should refuse to admit that the sentiment of egotism could reach the degree to which we see it carried in the starving man. Hunger speaks louder than laws, religion, feelings; all is hushed before its imperious commands."

In the case of Lieutenant Greely, who was exposed to slow starvation in the late Lady Franklin Bay Expedition, the following record was made by Dr. E. H. Green, June 22d, 1884, the day of rescue: "On admission fainted after being carried below in the wardroom, and vomited. Nervous system: excitable and irritable, at times almost emotional, eyes wild and staring; insists on talking, craving news, and demanding food, complains of no pain." His bodily weight was then one hundred and twenty pounds. In August, 1883, it had been one hundred and sixty-eight pounds. The next day: "No sleep, mind more tranquil but too active, great desire to talk and read; less persistent in demanding food; complains of soreness in limbs. June 25th, marked improvement, mind more tranquil; talks quietly without excitement; slept two or three hours naturally, awoke refreshed." After this there was steady improvement. The details in regard to the other organs of the body are purposely omitted, as not being relevant to our subject, but there was no organic lesion anywhere. All the symptoms here present were probably due to lack of food.

We must here again emphasize the fact that in these cases it is impossible in the present state of our knowledge to decide how far these symptoms are actually due to a condition of cerebral anæmia, or whether, as some observers think, there is present a fluxional hyperæmia of the brain.

Some of the symptoms present in cerebral anæmia deserve especial consideration, and among these we should place first the disturbances of the organs of special sense. Tinnitus aurium is one of the commonest symptoms of cerebral anæmia, even in its lighter forms, and is usually accompanied or followed by partial deafness. It is probable that these symptoms are due, at least in part, to irritation of the auditory nerve, for although the blunting of the mental perception might readily be adduced as the cause of deafness it could hardly be held to produce a ringing in the ears. Abercrombie's oft-quoted case of a much-weakened and anæmic patient, who was deaf when he sat upright but could hear well when he lay down, or when his face was reddened, would tend to confirm this view. In the same way the appearance of specks before the eyes and the blurring and dimness of vision which so frequently occur may be referred to irritation of the optic nerve. The occasional occurrence of total amaurosis would also seem to point to this. It is most common after severe hemorrhage, especially from the stomach, rarer in connection with inanition. It may or may not be accompanied by severe pain in the head. It may come on suddenly in the course of a few hours or it may take several days to develop. Travers says: "It succeeds somewhat abruptly to uterine flowing and large and sudden depletion for acute diseases. The pain is not confined to the region of the orbit, though it affects chiefly, if not exclusively, the same side of the head; it is that peculiar nervous pain to which women are subject after uterine hemorrhage, attended with a sense of defined pressure, as of an iron finger on the brain, and sometimes a distressing, jarring noise, like that of a mill or threshing-floor, or the rattling of the shingles as a heavy wave of the sea recedes." Samelsohn found cause in one case to suspect hemorrhage into the sheath of the optic nerve. A. von Graefe in his cases found nothing on immediate examination, but afterward atrophy of the optic papilla. Schweigger (Transl., Philadelphia, 1878) declares that the relation between loss of blood and disease of the optic nerve is wholly unexplained and that the latter cannot be due to simple anæmia.

Disorders in the sphere of the motor nerves may be either convulsive or paralytic. Kussmaul and Tenner have shown conclusively that in rabbits convulsions are almost uniformly produced in cases of rapid, profuse hemorrhage, or where the great arterial trunks leading to the brain are ligatured, except in the case of very weak animals or in such as were under the influence of ether. They found, however, that closure of all four of the arteries, both carotids and both vertebrals, was necessary in order to produce rapid convulsions. In all their cases the convulsions were epileptic in character.

In man convulsions have been noticed in connection with fainting, from the earliest times. Hippocrates says in his Aphorisms: "Σπασμοὶ γίνονται ἢ ὑπὸ πληρώσιος ἢ κενώσιος" (convulsions arise either from plethora or from anæmia). Marshall Hall, in his observations on blood-letting, declares that "convulsion is, after syncope, the most familiar of the immediate effects of loss of blood. It is most apt to occur in children and in cases of slow and excessive detraction of blood." . . . And again: "It is most apt to occur in cases in which the patient has been freely bled in a more or less recumbent position, in which the blood has flowed slowly, or in which time has been lost during the operation."

Anæmic convulsions rarely occur except after hemorrhage, when the amount of blood lost must be considerable. The loss must occur all at once, or nearly so, and the patient must not have been previously in a much debilitated condition. Thus, children in a hydrencephaloid state, and persons suffering from chronic anæmia, are not likely to be attacked with anæmic convulsions.

In contradistinction to convulsions *complete* paralysis without coma does not occur in universal cerebral anæmia, though after ligature of a carotid temporary hemiparesis and paralysis are not uncommon. If the paralysis be permanent there is probably some organic lesion present.

The general weakness of the limbs in syncope may be regarded as a form of paresis. "Cheyne-Stokes respiration and Traube-Hering blood-pressure curves are very common in states of partial anæmia of the bulbar centres" (Hill).

The DIAGNOSIS of anæmia of the brain, except in those cases of partial anæmia due to the obliteration of blood-vessels, which do not come under consideration here, can be made only through consideration of the accompanying general symptoms. Inasmuch as in hyperæmia of the brain the local symptoms are in many cases the same as in anæmia, the differentiation of these two opposite conditions will depend much on the history of the case. Even the condition of the vessels of the face and head is no positive proof of the condition of the internal vessels, nor would an increase or diminution in the supply of blood in the retina afford more than a presumption that the same condition existed in the meninges. The condition of the heart and the influence of posture and of alcoholic stimulants afford further aid in determining the diagnosis.

The PROGNOSIS in common cases of syncope is decidedly favorable, although even in ordinary cases of fainting from mental influences fatal results now and then occur. Less favorable is it in cases due to severe hemorrhage, even when not complicated by shock. On the other hand, in those cases of acute syncope where we have reason to suspect some weakness or lesion of the heart,—for example, in all cases of cardiac disease, and in convalescence after acute febrile diseases,—the prognosis is more serious. This especially applies to those cases in which the immediate cause of the syncope is some sudden change of position. In cases of chronic anæmia in the adult, syncope, as a rule, is not in itself a very serious symptom, but whenever a prolonged coma occurs, especially if accompanied by convulsions, there is cause for anxiety. In the hydrencephaloid condition in children, if the patient be seen and the disease recognized in time, recovery is probable under judicious treatment. The prognosis must in all cases depend, in this as in other diseases, in great part upon the severity of the symptoms. The condition of the pupils is said to form an important element in the prognosis, contraction always preceding dilatation, while they become normal again as the patient approaches recovery.

TREATMENT.—In simple syncope from mental emotion or from reflex irritation but little treatment is needed, except that the patient should be placed in a horizontal position and should be allowed plenty of fresh air, when recovery generally occurs quickly. Stimulants, such as ammonia, applied to the mucous membrane of the nose and air passages, are of assistance. As the syncope becomes more severe, we employ cutaneous stimulants, the simplest and best of which is the sprinkling of cold water over the face and chest. Mustard may be applied to the skin, especially over the cardiac region; but the most effective external stimulant is the electric brush. Internal cardiac stimulants, such as coffee, alcohol, or ether, are often of decided benefit. The carbonic dioxide in champagne is said to promote the rapid absorption of the alcohol, and hence this form should, when convenient, be used. In the severer cases, when the unconsciousness becomes prolonged, especially in those in which the loss of blood has been very great, the limbs should be bandaged, so as to drive all the blood as far as possible into the body and head. As a last resort, transfusion should be attempted.

In cases of chronic anæmia all means should be used to improve the general condition and strengthen the bodily forces. Milk is often the best form of nutriment, but when it can be borne a generous diet, including eggs and meat, is advisable. Wine is frequently of benefit when given in suitable doses, and in severe cases it is often indispensable. Alcohol is generally of much importance in cases of hydrencephaloid, and in these Nothnagel recommends the early use of musk. In all cases the surface of the body should be kept warm, if necessary, by the direct application of heat.

When mental excitement exists, all cutaneous stimulants or irritants are to be avoided, as they are said to increase the pain and restlessness. Under these conditions opiates often act well, better probably than chloral, which has also been recommended by good authorities.

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BRAIN AND NERVES, CHEMISTRY OF.—The proportion of water in the nervous tissues varies at different ages and in different parts. It is more abundant in the gray than in the white matter and in early than in adult life. In the gray matter of the adult it forms about eighty-five per cent. of the total constituents, in the nerves about sixty-five per cent.

The solids comprise the following:

1. Proteids, including nucleo-proteids, globulins, and, according to some, albumins.
2. Substances rich in combined phosphoric acid: nuclein, protagon, lecithin.
3. Complex nitrogenous substances, yielding a carbohydrate on decomposition and known as cerebrosides.

4. Cholesterin, a complex alcohol ($C_{27}H_{45}OH$).
5. Neurokeratin, a substance resembling ordinary keratin (from hair, etc.) and found in neuroglia and the medullary sheaths.
6. Extractives: Kreatin, xanthin, hypoxanthin, inosit, lactic acid, uric acid.
7. Inorganic salts.

Several of the above call for a brief note.

Nuclein is a compound formed by the union of a proteid with nucleic acid. Nucleic acid is phosphoric acid, P_2O_5, combined with a member of the purin group (xanthin, hypoxanthin, adenin, guanin).

Protagon, discovered in 1865 by Liebreich, was stated by Hoppe-Seyler and others not to be a definite substance but a mere mixture. Recently, however, its existence has been confirmed by numerous workers. Gamgee and Blankenhorn suggest $C_{160}H_{308}N_5PO_{35}$ as its empirical formula, but others claim that it may be found in several closely related varieties. On decomposition it yields one of the cerebrosides and the decomposition products of lecithin (fatty acids, glycero-phosphoric acid, and cholin). It may be obtained as a loose, white powder. It dissolves in eighty-five per cent. alcohol at 45° C., but separates on cooling as a snow-white, flaky precipitate consisting of balls or groups of fine crystalline needles.

The *Cerebrosides* are complex nitrogenous substances, yielding among their products of decomposition fatty acids and a carbohydrate (galactose). A number of varieties have been described, among which the best recognized are cerebrin, homocerebrin, and encephalin. Kossel and Freytag give the formula of cerebrin as $C_{70}H_{140}N_2O_{13}$, and of kerasin or homocerebrin as $C_{70}H_{138}N_2O_{12}$.

The relative proportions of the above-mentioned substances vary in different parts of the nervous system, but the following figures are probably approximately correct.

The total solids vary from 10 to 40 per cent. and are made up as follows: Of the total solids: Proteids, 25 to 55 per cent.; nuclein, 1 per cent.; protagon, 5 to 10 per cent.; lecithin, 10 to 30 per cent.; cerebrosides, 0.5 to 10 per cent.; cholesterin, 10 to 50 per cent.; neurokeratin, 3 to 6 per cent.; salts, 0.5 to 2 per cent.

The proteids are most abundant in the gray matter, cholesterin and the cerebrosides in the white matter. The salts are given as follows by Geoghegan in parts per 1,000 of brain:

Total ash	2.9	to 7.1	Chlorine	.4	to 1.2
Potassium	.6	to 1.7	PO_4	.9	to 2.0
Sodium	.4	to 1.1	CO_3	.2	to .7
Magnesium	.0	to .07	SO_4	.1	to .2
Calcium	.005	to .02	$Fe(PO_4)_2$	.01	to .09

The reaction of the central nervous system, especially the gray matter, has been stated by many writers to be acid during life, but according to Halliburton it does not become so till shortly after death.

T. Wesley Mills.
William S. Morrow.

BRAIN, ANEURISM OF ARTERIES OF.—Aneurisms of the cerebral vessels (independently of the miliary aneurisms which are treated of in the discussion of Cerebral Hemorrhage) are comparatively rare, though Coats makes the surprising statement that, "in persons under forty years of age cerebral hemorrhage is due to the rupture of aneurisms in the great majority of cases."

These aneurisms are situated commonly on the arteries of the circle of Willis, and, according to Lebert, the vessels are affected in the following order of frequency: basilar, middle cerebral, internal carotid, and posterior communicating, and the artery of the corpus callosum. The middle cerebral and basilar are involved in more than half the cases. The other vessels are only exceptionally the site of this lesion. Robertson reports a case in which an aneurism had burst into the right lateral ventricle. It was situated on a branch of the right middle cerebral artery, and had hollowed out a bed for itself in the substance of the corpus striatum and optic thalamus.

According to the majority of writers, the vessels of the left side appear to be affected more frequently than those of the right side, but in Coats' eleven cases all were situated on the vessels of the right side of the brain. The male sex seems to furnish a much larger proportion of the cases than the female sex.

The anatomical structure of cerebral aneurisms is entirely similar to that of similar lesions in other vessels of the body, and therefore need not be discussed here. They vary from the size of a pea to that of a hen's egg, though tumors of the latter dimensions are extremely rare. As a rule, they do not exceed the size of a hazelnut.

The immediate causes of the origin of this lesion have not been ascertained very clearly, but there appears to be little doubt that it does not bear such close relations to atheromatous degeneration as aneurismal dilatation of other vessels of the body. In a considerable proportion of cases the aneurism is the result of embolism, and this explains its comparative frequency at an early age (endocarditis, heart disease). Imperfect closure of the vessel by the embolus leads to inflammatory changes in the walls of the vessel, and, as the lumen is still partly open for the passage of blood, the weakened walls yield to the blood pressure and an aneurism is gradually produced.

Syphilis acts in a similar manner by weakening the walls of the vessels.

The lesion has also been attributed to the effects of injury to the head.

The aneurism produces various local effects. When situated in the circle of Willis it may cause erosion of the bones at the base of the skull. As a matter of course, it also produces pressure on adjacent soft parts, and as the circle of Willis is usually involved, the various cerebral nerves are mainly subject to compression, then the medulla oblongata, pons Varolii, and crura cerebri. Klippel reports a case in which an aneurism of the right posterior communicating artery, as large as a walnut, had compressed the adjacent brain substance from the edge of the pons to the right optic nerve. During life the patient had suffered from ptosis of the right side and complete immobility of the right eye, with disturbance of vision on both sides.

The aneurismal sac may also press upon adjacent vessels and give rise to thrombosis, with its usual train of sequences. In other words, the pressure effects are very similar to those of other forms of tumor situated at the base of the brain. An aneurismal murmur has been heard in a few cases, on auscultation of the skull. In still rarer cases this murmur has been heard by the patient himself.

When the aneurism is situated upon the basilar artery it is apt to give rise to hemiplegia. According to Lebert, this occurred nine times in thirty-one cases. Schmidt reports a case in which a diagnosis of cerebral hemorrhage had been made:

A man, aged fifty-seven, had an apoplectic attack with unconsciousness, left hemiplegia, including the facial nerve; the pupils were sensitive to light; sensibility was intact. The condition of the lower limb improved considerably, the arm became contractured. Death occurred two years later from pneumonia.

The autopsy disclosed a cylindrical aneurism of the basilar artery, extending from the lower end of the pyramids on the left to the corpora candicantia on the right. There was a depression of the pyramids in the medulla oblongata, and its edges were softened; also a depression in the pons, chiefly on the right side. There was distinct gray degeneration of the left lateral column of the cord and median bundles of the right anterior column.

Although, as I have stated above, the symptoms of cerebral aneurism are usually very similar to those of other kinds of tumors situated at the base of the brain, it differs from them in the fact that choked disc is a very rare symptom in the history of the former affection. In this respect it is somewhat similar to cerebral abscess, and, like the latter, it may also remain latent until the occurrence of a sudden apoplectiform attack, due to the rupture of the vessel. In quite a number of instances it has been found that the first rupture of the vessel did not prove fatal, and that a second rupture occurred after a variable period, sometimes extending over a couple of years.

The majority of writers assert that the rupture of the aneurism gives rise to meningeal hemorrhage; but this opinion should be revised in view of the fact that in all (eleven) of Coats' cases, and in a number reported by other observers, the hemorrhage took place into the substance of the brain. The extravasation is generally so extensive that it breaks through the brain tissue into the lateral ventricles, and often also into the other ventricles.

Treatment of this affection is altogether futile. The most that can be done is to relieve the pain (which is often even more excruciating than that caused by other forms of cerebral tumor) by the administration of morphine. Trial may be made of potassium iodide, as in aneurism in other parts of the body.

Leopold Putzel.

BRAIN, ATROPHY OF.—As applied to the brain, the term atrophy embraces the results of three different kinds of morbid processes. In the first two there is really atrophy in the ordinary meaning of the term—that is, loss of substance through previously existing disease. Thus: First, loss of substance, either from idiopathic disease inherent in the brain, progressive general paralysis; or associated with general disease, infectious fevers; or, from failure of nutrition, senescence, insanity. Second, loss of substance from destruction of tissue, or from a sclerosis secondary to localized destructive lesions. In the third class there is no proof that a tissue once existing has been destroyed, and the term atrophy can be used only by a certain license. But for practical convenience there are many reasons for ranking the cases in question with the atrophies. They are, third, cases of imperfect development of the brain, cerebral agenesia, partial or general (microcephalus).

This classification of cerebral atrophies is traversed by another division into congenital and acquired; since many cases of arrested development of the brain are clearly traceable to diseases identical with those which occur after birth. The agenesia is then secondary, and except from its intra-uterine origin, could be referred to the second class of cases.

Congenital, Primary, and General Atrophy of the Brain constitutes microcephalus, the rarest form of idiocy (Ireland). No destructive lesion is discernible, but the size of the brain as a whole is much below normal, and the internal proportion of its parts is disturbed. The dimensions of the cranium correspond to those of the brain, and thus during life the size of the latter can be estimated by measurements of the former. Normal mental faculties are impossible with an adult head of from eleven to thirteen inches in circumference and from eight to nine inches from the root of the nose to the posterior border of the occipital bone. A circumference of fourteen to seventeen inches and an antero-posterior diameter of eleven to twelve decimetres implies a brain too small for ordinary intelligence (Voisin). Ireland calls microcephalic all adult heads below seventeen inches in circumference.

The lightest human brain on record weighed six ounces, in a child five months old (Sanders). In this the circumference of the head was less than six inches. Several brains are described of seven ounces (normal weight for men, forty to fifty-two and one-half ounces; for women, thirty-five to forty-five ounces. In microcephalic brains, the frontal lobes taper to a point; the occipital lobes either taper, or are much shortened, in either case exposing more or less of the cerebellum. The parietal and temporo-sphenoidal lobes are the best developed. The corpus callosum is often thinned, or shortened at its posterior end. The island of Reil may be left uncovered. The convolutions are remarkably simple; few secondary folds are developed. The disposition of many sulci is changed, the fissure of Sylvius shaped like a **V**, instead of a **Y** (Vogt); the calcarine fissure is prolonged so as to separate the gyrus fornicatus from the gyrus hippocampi (Putnam-Jacobi), the bridging convolutions of the occipital lobe are indistinct or wanting (Betz). In a celebrated hypothesis, microcephalic brains have been considered to constitute anatomic reversion to the ape type (Vogt). There is, however, no constant resemblance between the two; the brain of the microcephale may be simpler than that of orang or chimpanzee, it is not similar (Gratiolet, Adriani).

The intelligence of microcephalic individuals who survive is rudimentary, but at various degrees removed from imbecility, complete aphasic idiocy. There is no definite proportion between the degree of intelligence and the size of the brain. In those who attain adult age a certain amount of speech is often possible, and there is some power of attention, memory, and emotionality. Sometimes the amount of intelligence is remarkable, if we consider the dimensions of the cranium (case, Antonia Grandoni; circumference of head, at age of forty-one, thirteen inches). There is usually full and restless use of the limbs, and the impressions of the senses are lively. The absence of local or general paresis distinguishes cases of pure microcephalus from those in which the arrest of cerebral development is associated with destructive lesions. Sometimes, however, the muscles are notably feeble, the characteristic restlessness of microcephaly is exchanged for immobility, varied by rhythmic, swaying motions (Meynert). In these cases there is probably nutritive alteration of the brain tissue; or deficient elaboration of its minute structure (Jastrowitz). There may be persistence of the molecular substance which precedes the formation of the medullary sheaths to the nerve fibres, or of the large granular fat cells, which belong to the transitional stage, and have been sometimes taken as evidence of congenital inflammation (Virchow).

Congenital Primary (?) and Partial Atrophy.—In this class of cases, one or more portions of the encephalic masses are absent, and no traces remain of destructive lesions sufficient to account for their disappearance. Thus they have been explained by a primary aberration of development. The explanation is most plausible in regard to partial or total defect of the corpus callosum (Hitzig). This great commissure begins to develop toward the end of the fourth month of pregnancy, by buds which appear on the internal lateral surfaces of the hemispheres, and grow simultaneously inward and backward. In partial defect it is the posterior portion of the corpus which is wanting, showing an arrest of the partly completed process. The arrest sometimes involves the fornix trigonum and septum lucidum, sometimes these are intact. In all recorded cases, the anterior white commissure is preserved. The lateral ventricles are distended. This fact suggests that an undeveloped corpus has been destroyed by a ventricular effusion, the latter subsequently reabsorbed. The cerebellum has several times been found defective. In one celebrated case, unique according to Hitzig, the organ was completely wanting, being reduced to two small knobs, at the base of a serous cyst which occupied its place under the tentorium (Cruveilhier and Combetta, case Labrosse). Hitzig explains this case by an arrest of development; the author, much more plausibly, by a serous apoplexy which had occurred in early or in fetal life. The loss of the cerebellum was accompanied by total absence of the pons; the pyramids arising directly from the cerebral peduncles. In Otto's case, the cerebellum was very much reduced in size by filling up of the occipital fossæ, through inflammatory thickening of the bones. The atrophy was therefore again a secondary lesion. Atrophy of the cerebral hemispheres is usually evidently traceable to destructive lesions. Sometimes, however, the traces of these have disappeared, and the atrophy then seems primitive. Cruveilhier describes the reduction of one hemisphere to one-third the size of the other. The space beneath the dura mater was filled with serous fluid. Isolated groups of convolutions are often atrophied: thus, lower part of the central convolution, with supramarginal and superior temporo-sphenoidal (Beach); central convolutions on one side (Virchow's *Archiv*, July, 1882);

central convolutions on both hemispheres (McNutt); right ascending parietal convolution (Bastian); right cerebrum, right crus, pons, and pyramid, left lateral pyramidal tracts (Pick); paracentral lobule, superior extremity of left ascending parietal convolution (Varigny). In many of these cases a primitive arrest of development has been assumed; in none is it demonstrated, or even probable (Steffen, Brouardel, Hasse). The entire class of cases should therefore be consolidated with secondary atrophies.

Congenital Secondary Atrophy.—This is partial or general, according either to the extent of the destructive lesion, or of the interference with the general development of the brain which may have been exerted by a localized lesion. Nutritive processes throughout the brain may be so disturbed that nerve tissues cease to grow, nutrition is diverted to the cranial bones, premature ossification of the skull occurs, with some degree of microcephalus.

On the other hand, with a fetal hydrocephalus, all the brain above the medulla may be destroyed and converted into a serous cyst, while the cranial bones continue to grow, until after birth the head attains a circumference of two feet (Cruveilhier).

The lesions leading to congenital cerebral atrophy are produced during fetal life, and do not differ essentially from those which may be occasioned during the process of parturition, or so soon after birth that the symptomatology becomes identical with that of strictly congenital lesions. They are, in addition to the hydrocephalic effusions just mentioned, hemorrhage, inflammation, and softening by steatosis.

Throughout fetal life the rapidly growing brain is exposed to a graded series of accidents, corresponding to varying tendencies to effusions from the cerebral blood-vessels—now serous, now sanguinolent. At a certain degree of intensity these dropsies or hemorrhages result in complete malformation of the brain (hydrencephalon, or anencephalon); more limited in extent, the effusion results in the formation of a cyst, whose contents may be clear serum, or serum stained with the coloring matter of blood. The cyst replaces whatever nerve tissue has been destroyed. Intra-uterine cerebral hemorrhage is much more liable to occur into the meninges than into the substance of the brain itself. A clot is then formed in the cavity of the arachnoid, and lying upon one or both cerebral hemispheres, which it is destined to compress during the process of its shrinkage. The subjacent tissues atrophy under the double influence of the pressure and of the sclerosis excited by its irritation.

Precisely such arachnoid hemorrhage, with consecutive atrophy, is a not uncommon accident of a difficult parturition; and is thus the efficient cause of many cases of idiocy and spastic contracture. Hemorrhage is also possible, but much less frequent, during the first months or year after birth. The cerebral atrophy, however, can be called congenital only when dating from accidents which occur previous to all distinct psychic developments, thus hardly after the first month.

Meningo-encephalitis is, during the period immediately succeeding birth, more frequent than hemorrhage, and also occurs before birth. An intense form, occurring at the third or fourth month of pregnancy, is probably the cause of the pseudencephalic monstrosity. Traces of a more tolerable, and even extensive, grade of inflammation are found in thickened brain membranes, enclosing shrunken masses of nerve tissue, or even empty of these. All but the most limited and localized cases of meningitis are liable to be complicated by hemorrhage from the tender blood-vessels. Localized basal meningitis may interfere with the development of the brain, and thus, if the paradox be permitted, cause a species of primary atrophy, with premature ossification of the skull. The most striking effect of such lesion, from its proximity to the optic chiasma, is a descending neuritis and atrophy of the optic nerves.

When a portion of the brain has been destroyed by either hemorrhage or inflammation, serum is poured out to fill the threatened vacuum. This non-encysted fluid is found both in the ventricles, in the cavity of the arachnoid, and in the subarachnoid space. It constitutes the so-called hydrocephalus *e vacuo*, which must always be interpreted as a secondary lesion, and not as the essential cause of the symptoms observed during life.

In certain cases a portion of the nerve tissue of the brain is found to have simply disappeared, sometimes throughout the entire depth of the hemisphere, thus leaving an opening which leads from the convexity pia to one of the ventricles (porencephalic defect, Kundrat). This lesion is not entirely peculiar to the new-born, for it has been found in adults after chronic brain disease (Cotard). In the new-born, however, it is due to a peculiar lesion, a steatosis of the nerve substance, which results in red or white softening, according as it is or is not complicated by vascular congestion and capillary hemorrhage (Parrot). The foci of steatosis contain a great number of granular corpuscles, due to the fatty infiltration of neuroglia cells; also free granulations and species of cylinders, resulting from deformation of the corpuscles of Gluge. The veins are occluded by thrombi. The nerve tissue is reduced to a milky pulp, and, if the process lasts long enough, is gradually reabsorbed. The lesion may be circumscribed to a mass the size of a filbert, or may extend nearly throughout a hemisphere. In the first case it is usually multiple; in the second, the corpus callosum is the most affected.

One of the most important anatomical consequences of any of the above-described lesions of the brain is a degeneration of the motor tracts which lead from the seat of the lesion to the lateral and innermost fasciculus of the anterior columns of the spinal cord (crossed and pyramidal tract). This degeneration involves two elements: atrophy of the myeline sheaths of the nerve tubes, and proliferation of the neuroglia tissue between them. These elements are combined in various proportions, and when the atrophic process predominates, it is difficult to say that a simple agenesia of the spinal cord has not complicated an arrest of development of the brain. The fibres of the pyramidal tracts assume their myeline sheaths much later than the other segments of the cord, beginning at the fifth month; but they should be completed at birth in the cord (Flechsig), though still incomplete in the cerebral peduncles (Parrot). Simple defect of these sheaths, therefore, without sclerosis, might, at birth or a little before it, result from a check to the developmental process, dating from some epoch of the sixth, seventh, or eighth month of intra-uterine life. A lesion occurring during the last month, at birth or shortly afterward, can determine only atrophy of the myeline sheaths through propagation of a nutritive irritation, which is further revealed in a co-existing proliferation of neuroglia. This, therefore, serves to distinguish between a primary and a secondary atrophy of the brain, the latter, except in steatosis, always involving irritation (see case McNutt). This degeneration can be traced by a column of grayish color, contrasting with the normal white, in the cerebral peduncle, half of pons and pyramid, on the same side as the lesion; and in the cord, through the posterior portion of the lateral column on the opposite side (Türck). A similar but much narrower gray tract occupies the inner part of the anterior column on the same side as the cerebral lesion. When the primary lesion is bilateral, the second is so as well. Under the microscope, the proliferated connective tissue is readily traced by its brilliant coloration with carmine. Descending degeneration may be observed after the steatosis of the brain, but much more rarely and less completely than at other ages or after other lesions; a fact which Parrot attributes to the incomplete development of the cerebral portion of the pyramidal tracts. The same condition should tend to avert sclerosis after any lesions which occur early in fetal life. Conversely, in the cases in which the symptoms of "spastic paralysis" indicate an extensive amount of secondary sclerosis, we may date the primary lesion back to near the moment of parturition.

According to Charcot, no cerebral lesions occasion secondary degeneration unless they involve the fibres of the anterior two-thirds of the internal capsule. These contain the superior fibres of the pyramidal tract. Atrophic lesions of the cortex are followed by diminution in the size of the corpus striatum on the same side, and, what is more singular, of the thalamus as well. The hemisphere of the cerebellum opposite to the lesion shares in the atrophy. When the lesion is localized primitively in one side of the cerebellum, the upper motor tracts are unaffected, but the olivary body on the opposite side wastes. Atrophic lesions of the basal ganglia are similarly followed by atrophy of the tracts below them, while those above remain unaffected. Lesions in the white substance of the hemispheres occasion no primary atrophy but what is due to direct loss of substance, and no secondary atrophy, unless they involve the fibres of the pyramidal tract (see *ut supra*).

Symptoms of Congenital Cerebral Atrophy.—These are of two kinds: 1, Visible lesions; 2, disturbance of functions.

1. Hemiatrophia facialis has been observed at birth, and then, plausibly, referred to a cerebral hemiagenesia (Emminghaus). No autopsies exist to confirm or annul this hypothesis. The hemiatrophia of the brain, if existing, could be a coincidence only of the lesion of the trigeminus, to which this singular affection is usually referred. The majority of reported cases are acquired after birth.

Unilateral or even monoplegic atrophy of the limbs is, however, frequently in cerebral hemiatrophia associated with motor paralysis and different forms of rigidity of the same limbs. Of the three symptoms, the paralysis is alone congenital; the atrophy of a limb or a segment of a limb, as a hand, is associated with diminished size of Ferrier's cortical motor centre for the part. It is questionable whether the cerebral atrophy is then the cause or the consequence of the peripheric lesion. Similar wasting of the cortical motor centre has been seen in an individual in whom the leg had been amputated many years before death. The cerebral atrophy was there evidently secondary. Many cases of congenital loss of the segment of a limb are due to intra-uterine amputation through ligature by amniotic bands. The accident then essentially resembles that of extra-uterine life.

Atrophy, in congenitally paralyzed limbs, appears after a time to be much more extensive than that of acquired cerebral paralysis. This is because the diminution of size depends principally upon interference with development. There is not loss of substance once acquired, but the affected limb remains behind its fellow in growth. Structural defects of the eye and ear are not unusual; thus, coloboma of the iris, eyelids, or retina, deformities of the external ear. Associated with the latter, as coincidently developed from the superior branchial arch, may be malformations of the mouth, harelip, cleft palate, etc. It is difficult to say, however, in what proportion the probability of such defects is increased by the existence of a cerebral atrophy compatible with life. Cerebral malformations of non-viable subjects are usually associated with other malformations of the body.

2. Disturbance of function. There are three in the motor sphere: Paralysis, rigidity, and convulsion; and to these must be added defect of intelligence. The sensibility is obtuse but not specifically affected. The paralysis is rarely complete, and by no means always localized. A general paresis of all the muscles of the body is the most frequent and earliest form of motor disturbance, even in well-defined unilateral cerebral lesions. The infant is able to move all its limbs, but cannot grasp with the hands, stand on the feet, sit up, or even hold its head up. Often after one, two, three, or four years the child acquires a certain amount of power in this respect. The motor paresis tends gradually to disappear, as in animals upon whom lesions of the cortical motor centres have been inflicted. When this happens, the cerebral lesion in children may also be referred to the cortex, and the basal ganglia be presumed to be intact. It is not infrequent, even, that congenital cortical lesions which render children incurably idiotic are unattended by any paralysis whatever.

The symptoms of rigidity are especially interesting. The muscles of a single limb, an arm, may be affected with transient attacks of rigidity, but they rarely assume the permanently rigid contraction seen as a late symptom in acquired hemiplegia. The most characteristic form is the spastic paraplegia of the lower extremities. This is by no means exclusively due to cerebral agenesia, for it exists without cerebral symptoms, as a symptom of primary cord disease. But when it is congenital, associated with defective intelligence or disorders in the range of the cranial nerves, it may certainly be referred to atrophia cerebralis. Many entirely superfluous hypotheses have been made in regard to this disorder. There are two forms. In one the muscles of the lower limbs are permanently rigid, and principally the abductors of the thighs, the hamstring muscles, and the gastrocnemii. From retraction of the rigid muscles the thighs are abducted, the legs partly flexed on the thighs, the feet on the legs. In the other form the muscles are supple while the child is recumbent, but the attempt to stand or walk is immediately followed by spasm in the muscles indicated, or only in the abductors, so that the limbs are approximated or even crossed.

The bilateral character of spastic paraplegia does not always imply a double lesion of the cerebrum, though this was demonstrated in one remarkable case (McNutt) and inferred in another (Hutchinson). The immediate antecedent of all the spastic symptoms observed is, as in the late rigidity of acquired hemiplegia, secondary sclerosis of the pyramidal tracts in the lateral columns of the cord. Ninety-one to ninety-seven per cent. of the fibres of these tracts are normally crossed, the remainder direct (Charcot). The probabilities are, therefore, that the sclerosis and rigidity remain limited to the side opposite the cerebral lesion. But in children bilateral spasm may occur, either because the relatively minute extent of sclerosis on the same side as the lesion in the direct pyramidal tract exercises a greater functional effect, or because the proportion of decussating fibres has varied, leaving a much larger number in the direct portion of the tract, or because there has been a second decussation of motor fibres in the cord below the pyramids (Charcot).

When spastic symptoms have developed, paresis of the rigid limbs is liable to be masked by them.

The third motor symptom, convulsion, is irregular in the time and frequency of its occurrence, and variable in its intensity. Convulsions coming on within the first week or two after birth generally indicate that the cerebral lesion upon which the atrophy depends has been caused during parturition. In cerebral atrophy of intra-uterine origin convulsions are delayed for several months after birth. They often coincide with the first symptoms of rigidity in the limbs, or precede these a little, and seem, therefore, to mark the development of the irritative lesion of degeneration. Convulsions are never due directly to the atrophy itself, but only to the secondary lesions, as they descend through the pons and medulla. The convulsion may consist in a momentary stiffening of the body, followed by clonic agitation of one or more limbs, or it may be a complete epileptiform paroxysm. The slighter forms are often frequently repeated, sometimes even in a single day; the complete attacks occur at longer intervals, of weeks or even months. The close approximation of severe convulsions is dangerous, and a not infrequent cause of death. The intelligence is invariably impaired when the atrophy affects either cerebral hemisphere, or both, and is often deficient even in atrophy of those portions of the encephalon whose share in mental processes is not well understood, as the corpus callosum or cerebellum. It is probable in these cases that the finer structure of the cerebral cortex is imperfectly elaborated, even when no gross lesion is visible.

The degree of mental defect varies from simple flightiness and moral obtuseness (cases of atrophy of the cerebellum) to complete idiocy, and all intermediate stages of imperfection of the intelligence are observed. The speech is sometimes disproportionately affected. There may be complete aphasia, yet the expression of the face and the actions indicate considerable intelligence. It is possible, then, as Gerhardt suggests, that the lesion is localized in the speech centre. In other cases there is no true aphasia, or inability to frame verbal conceptions, but articulation is interfered with by spasms of the facial muscles, analogous to those excited in the limbs by the attempt to use them.

Complete idiocy can be recognized in babies of three or four months old by the vacant expression of face, the inability of the child to recognize its mother or nurse, its inattention to all the usual objects of baby interest, the absence of the smiles and cooings of a healthy child. The slighter the degree of mental defect the later is its recognition possible, as it will become apparent only as the conditions of existence become complete.

The cranial nerves are often involved in either the primary lesions which have caused the atrophy or in the lesions secondary to them. Optic neuritis with secondary nerve atrophy may occur independently of any conditions of increased intracranial pressure. It is then attributable to a descending cerebritis. Early blindness in an infant renders detection of mental defect difficult or impossible. With or without blindness, irritative lesions of the sixth or third nerve may occasion strabismus or nystagmus. Coloboma of the iris, as well as congenital defects of other parts of the body, is not infrequently present.

Acquired Cerebral Atrophy.—This is always secondary, but may be general or partial.

General atrophy of the brain is found to a certain extent in all prolonged wasting diseases, especially phthisis. It is conspicuous in senile decay, but is not associated necessarily with any particular age. The brain is heaviest at thirty, but while some brains begin to degenerate at sixty, others resist decay at eighty or even older. The brain is always wasted in alcoholism, and also in chronic insanity, usually as a whole, sometimes more markedly in one hemisphere, or in certain lobes, especially the frontal. The most conspicuous general atrophy is seen in diffuse meningo-encephalitis (general paresis of the insane). The total weight of the brain may sink in this disease below 1,000 gm. (minimum normal weight for man, 1,130 gm.), and abundant serum may accumulate in the sulci. The frontal lobes are the most shrunken; after them the central convolutions; the cerebellum is always intact (Hitzig).

In all cases of chronic insanity, and most markedly in those of general paresis, the ganglionic cells of the cortex degenerate, become filled with fatty and pigment granules, and lose their protoplasm, nucleus, and axis cylinders.

In general cerebral atrophy both hemispheres are found sunken, retreating from the cranial bones, and the convolutions are thin and small, separated by wide furrows. In these enlarged sulci, as also in the dilated lateral and third ventricles, a serous effusion replaces the brain substance, as in congenital atrophy. The cortical cover of the ventricles may be so atrophied that the arachnoid and pia come in contact with the ependyma entirely, or in limited spaces, constituting an acquired porencephaly.

Generalized atrophy may also result from localized lesions of the cortex, whose ganglionic cells seem to have an influence on the general nutrition of the brain, analogous to that of the ganglionic cells of the cord on the peripheric nerves. Finally, mental inactivity predisposes the brain, as other unused organs, to atrophy. Thus probably is explained the frequency of premature senile atrophy among peasants and other uneducated people.

Partial atrophies occur at the seat of a destructive lesion, and also in regions functionally correlated with this. Of such lesions, hemorrhage is relatively less prominent than in fetal life: embolism and thrombosis from atheroma of blood-vessels are the most frequent. Both are attended by red or white softening, or even by true localized encephalitis; the brain cortex may be infiltrated with leucocytes following the track of blood-vessels, and evidently exuded from them; and also with the granular corpuscles of Gluge, resulting from fatty infiltration of neuroglia cells. To these processes are due the characteristic yellow patches so frequently found on the cortex of the brain, varying from an entirely insignificant size to the entire surface of a hemisphere, and sometimes penetrating its entire thickness (Cotard). Cysts and sclerosis may be found in adult life as in congenital agenesia, and the waste of nerve tissue may result, in either case, in simple defect; but the yellow patches are peculiar to acquired atrophy. The cysts are surrounded by an ochre-colored zone, where the nerve tissue has been stained by hemorrhagic effusion. Localized meningitis, or the outward-bearing pressure of a ventricular effusion, may also determine atrophies, either partial, or, in the latter case, symmetrical and generalized. Tumors of the brain necessarily determine atrophy of the nerve tissue they replace; but on their periphery there is an irritative hypertrophy, due, however, to proliferation of the neuroglia cells (Adamkiewicz). A band of this same sclerosis surrounds the focus of any destructive brain lesion. In senile atrophy occurs the vacuolation of the brain, long known as "l'état criblé" (Durand-Fardel), due to the enlargement of the lymphatic spaces surrounding the blood-vessels. This dilatation results from prolonged and intense hyperæmia. Hasse observes that in partial atrophy the primary destructive lesions affect all elements of the brain substance; in secondary atrophy the nerve elements alone. But in general diffuse atrophy, as from diffuse meningitis, an irritative process is first initiated in the neuroglia, and the nerve elements gradually waste. A linear cicatrix never forms in the brain, whose tissues are incapable of retracting; but there is always a space to be filled by a liquid, or by débris, or by newly formed connective tissue.

The *symptoms* of acquired cerebral atrophy are essentially the same as those of cerebral agenesia, but differently combined, and existing in different proportions. When the lesion occurs in adult life, it can cause no arrest of development in the limbs, such as is so common in agenesia. Partial paresis or paralysis may be produced when the lesion is situated in the motor tracts. But superficial patches of atrophy of the central convolutions may be found in persons who had completely recovered from the paralysis caused by the initial lesion. As in agenesia, the rigid contractions of paretic or paralyzed muscles develop together with the secondary degenerations; the "late rigidity" of hemiplegics is not the immediate consequence of the primitive lesion. This rigidity occupies by preference the superior extremity, and is often confined to that, even when the lower extremity is also paralyzed. It acts in the sense of flexion, so that the arm is drawn to the side, the forearm partially flexed, the two last phalanges of the fingers flexed, while, from atrophy of the interosseous muscles, the first phalanx is allowed to be extended. Hence results the "claw-hand" as characteristic of hemiplegia. Tremors, localized clonic cramps, and general epileptiform convulsions occur. The latter may precede the cerebral atrophy and indicate the progress of a localized meningitis, of which this atrophy is to be the result; or they may indicate the progress of a descending sclerosis toward the pons; or they may announce the termination of the whole morbid process. Convulsions are most frequent with lesions of the cerebellum, the cerebral cortex, and the ventricles; but these belong to the primary process, not to the atrophy itself. In the former case other symptoms coincide—febrile attacks, temporary strabismus, irregularities of the pupils, headache. In the latter any mental deficiency previously existing deepens, even to dementia, and as the end draws near the patient becomes comatose. In the atrophy of general paresis, the loss of muscular power is an early and prominent symptom. There is no rigidity. The mental defects in acquired cerebral atrophy are even more varying in nature and degree than the motor symptoms. Sometimes for many years these may be absolutely nil; then, if the atrophy progresses, the mental powers become gradually impaired. Simple failure of the intelligence is usually proportioned to the extent of the lesion; qualitative alterations of special faculties bear a more or less definite relation to the seat of the lesion. The dissociations of the speech faculty are numerous, giving rise to aphasia, amnesia, agraphia, alalia, and their combinations. Failure in memory, as in all chronic cerebral disease, is one of the earliest mental defects; the moral sense, dependent on the ethical mechanisms, the most delicate of all (Griesinger), is blurred.

Localized atrophies have been of great service in investigating the problems of localization in cerebral functions.

Prognosis of cerebral atrophy depends upon the extent of lesion, and upon its stationary or progressive character. When only a limited amount of brain tissue is destroyed, its function may be vicariously performed by another portion, and the loss thus repaired. This is impossible with extensive acquired lesions. In the famous cases of congenital atrophy of the cerebellum or corpus callosum, however, the functions of these parts must have been performed by other organs, for their defect could not be diagnosed during life.

A broad distinction exists between the prognosis of congenital and that of acquired atrophy, in that the former far more frequently coincides with an arrested morbid process, the latter with one that is either continuously progressive or liable to renewal after temporary arrest. The mental defects due to atrophy of any portion of the adult brain cannot be repaired; the utmost to be expected is their limitation; the probabilities are that they will steadily or intermittently increase. On the contrary, in a brain partially atrophied while still in process of development, a vigorous psychic education may often hope to develop faculties by exercise of the intact portions. The difficulty of doing so increases with any form of disturbance of the speech faculty. Congenital paresis tends spontaneously to diminish, and muscular power may be greatly increased by systematized gymnastics. The paresis of acquired atrophy, unlike the paralysis due to destructive lesions, tends to permanence or to increase; the latter case being the rule in the general paresis of the insane. Muscular rigidities, contractures, and the deformities of limbs caused by them, increase for a long time in congenital cases, first as a result of the extending spinal degeneration, then as a consequence of malposition and adaptive shortening. The latter cause may be greatly palliated by appropriate apparatus; and the prognosis in respect to deformity, and to the power of walking and other use of the limbs, is hopeful in direct proportion to the influence of malposition, and inversely to that of the lateral sclerosis. Corresponding to the lesser extent of the brain lesion, the deforming contractures of acquired atrophy are much more limited, and therefore of less importance; their degree of amenability to therapeutic palliation is about the same. General acquired atrophy is not followed by deformity, for all the muscles are equally affected. The duration of life is quite indefinite. Death is never the direct consequence of the atrophy, but results from asthenia due to the progressive impairment of brain nutrition; from œdema, as the walls of the blood-vessels become more altered; from convulsions, especially associated with extension of secondary irritation; or from renewal of the primary accidents (hemorrhage, thrombosis, meningo-encephalitis, etc.).

Treatment is palliative, and in the directions implied in the remarks on prognosis. The primary morbid process, if still going on, must be treated by appropriate measures; and an important point of the diagnosis is the decision whether this primary process is or is not arrested. In congenital atrophy, the mental faculties must be awakened as far as possible by psychological education, which, to attain the end, must be both persevering and profound. The muscular paresis must be combated by gymnastic exercises, the deformities by apparatus able gradually to stretch retracted muscles, to support limbs in proper position, and by means of springs and artificial muscles to facilitate attempts at voluntary movements. The proposal to relieve the deformities due to rigidity of the adductor femoris muscles by circumcision—an operation intended to relieve a hypothetical genital irritation—is most irrational. If relief ever follow this operation, it can be only in cases of entirely different character, a purely functional spasm, possibly associated with masturbation, and having nothing to do with lateral sclerosis of the cord. The convulsions which are so common in congenital atrophy require the usual treatment. For the eye symptoms (blindness, strabismus, nystagmus) nothing can be done.

In acquired atrophy treatment mainly consists in averting conditions which are likely to revive the primary accidents, and in treating these as they arise. The earlier in life the cerebral lesion occurs the more the conditions approach those of congenital atrophy; and when the accidents date from the first years of childhood the practical treatment is identical for the two classes of cases. Conversely, as a patient approaches old age, both the primary accidents and the atrophy are more liable to be progressive, and the rôle of the therapeutist becomes more purely passive. There can be no longer question of developing a brain, checked in its evolution, but only of shielding it from new injuries which would cause fresh deterioration of faculties; hence mental strain and excitement of all kinds are to be avoided. The keynote of the treatment is the necessity for repose for the nervous processes proper and for the cerebral circulation. Regulation of the social medium is the principal factor for the first; of exercise and climate for the second. Apparatus for deformity is less needed and less tolerated than in children. The contractures principally affect the upper extremities, instead of, as in children, the lower; and it is much more difficult to facilitate the functions of the arms than of the legs by prothetic apparatus. Still, with ingenuity, this may sometimes be accomplished.

Diagnosis.—In congenital or early cases it is principally necessary to distinguish between primary and secondary cerebral atrophy, and between the latter and the various lesions upon which it depends, as hydrocephalus, hemorrhage, meningo-encephalitis. Primary atrophy may be inferred from deficient or idiotic intelligence, without motor disturbances or lesions of the special senses, while hydrocephalus may be excluded from the size of the head. The extreme degrees of diffuse primary atrophy constitute microcephalic idiocy, and are recognizable usually from the minute proportions of the cranium. The diagnosis cannot, however, always be made, for, though rarely, large portions of the encephalon may be absent, without any more defect in the intelligence than is often observed without gross cerebral lesion at all. And, on the other hand, the destructive lesion causing a secondary localized atrophy may be so limited that the descending degeneration occasions no characteristic symptoms, yet the finer mechanisms of the brain may be so jarred that the evolution of the mind is permanently impaired. In any case in which the associating fibres or the superadded convolutions (Broadbent) are affected, while the motor fibres prolonged from the crus remain intact, imbecility with preservation of muscular function is possible. In secondary atrophy, if the primary morbid processes have been arrested before they have been discovered, or at birth, it is often difficult, in the latter case impossible, to distinguish between them. Congenital hydrocephalus is recognizable when the head is already enlarged at birth, and may be a cause of dystocia. When the head begins to enlarge within a few weeks after birth, it is probable that ventricular effusion has already begun before. The probability is greater if spina bifida coexist. In such cases it is sometimes the symptoms of the effusion, sometimes those of the atrophy and spinal sclerosis, that predominate. An extra-uterine cerebral hemorrhage or attack of meningo-encephalitis is indicated by the usual signs; but these are liable to be masked in infancy by convulsions and fever, common to both, and also to so many other infantile disorders. Persistence of an inflammatory process may be indicated by irregular recurrence of fever, associated with pain, retraction of head, pupillary symptoms, and other characteristic signs of meningeal irritation. Still these may also be aroused by the irritative process of degeneration, especially when this reaches the motor tracts in the pons and medulla. It may be said that in secondary atrophy at any age, the diagnosis may be made by the coincidence of three symptoms: mental defect, muscular paresis, and muscular contracture; these coming on gradually or after a period of stormy cerebral accidents. The various other symptoms enumerated may or may not be present; among them lesions of the cranial nerves are of the same order as the rigidities of the limb muscles, and, like them, may be referred to the descending sclerosis accompanying the atrophy. Convulsions and fever may be due to this or to persistence or revival of the primary process.

Mary Putnam Jacobi.

BRAIN: CEPHALOCELE.—(Synonyms: Encephalocele, Hydrocephalocele, Hydrencephalocele, Cephalhydrocele, Meningocele, Hydromeningocele, Craniocele, Hernia seu Fungus seu Ectopia Cerebri). Hernia of the brain or meninges is a name given to a protrusion of a portion of the contents of the cranial cavity through an opening in the skull beneath the scalp. There is need of greater simplicity in what is now a rather confusing terminology, and it would seem that the best designation for all of these tumors as a class is cephalocele. There is a correspondence in application between this word and enterocele because of the similarity of their constituents. There is a hernial canal or opening in the skull, a hernial sac consisting of the dura mater, the hernial contents composed of whatever substance or fluid may be forced out from the cranial cavity, and, finally, the various coverings of the hernia, such as the pericranium, fascia, and skin. It is necessary, in a true cephalocele, that the dura mater form the hernial sac. The tumors formed beneath the scalp in traumatic lesions of the skull and dura, by the pouring out of cerebro-spinal fluid, are not true cephaloceles, and are more properly termed *pseudo meningoceles*. Protrusion of brain substance in compound fractures of the skull is not considered here, though sometimes improperly called a hernia cerebri; the correct designation is *prolapsus cerebri*.

The varieties of cephalocele depend upon the contents of the tumor. Hence we have a *meningocele* where the hernial contents are cerebro-spinal fluid alone pressing out the dura mater; a *hydrocephalocele*, where the tumor consists of an internal hydrocephalus expanding and forcing outward the ventricular walls; and, finally, an *encephalocele*, composed wholly of brain substance with more or less fluid usually surrounding it.

These tumors are mostly of congenital origin, but there are certain rare cases in which they are acquired after birth, through disease of the cranial bones or traumatism. It is usual, therefore, to distinguish two forms of cephalocele, the congenital and the acquired. In describing the latter it will be best to use the prefix *pseudo*.

Congenital Cephalocele.—These tumors almost always have their peduncles at or in the immediate neighborhood of some cranial suture. The great majority are in the antero-posterior median line, as a rule either in the frontal or in the occipital region. According to Giovanni Reale, who collected 68 cases of cephalocele, 10 were at the nasal root, 9 in the frontal suture, 5 at the posterior fontanelle, and 22 in the occipital bone, the rest arising from some of the lateral sutures. Larger tabulated 85 cases, 44 of which were occipital and 41 frontal or sincipital. The favorite location of the sincipital tumors is at the root of the nose, either at the inferior part of the frontal suture or at the junction of the ethmoid and frontal bones. The hernial canal or opening is generally bounded by the separated or more or less malformed ethmoid, frontal, nasal, or lachrymal bones, and sometimes even by the nasal process of the superior maxilla. Fenger (*Am. Jour. Med. Sciences*, 1895, cix., 1), in an article entitled "Basal Hernias of the Brain," describes such sincipital tumors as differ from the others in not protruding in the face. The least uncommon form is the spheno-pharyngeal cephalocele, protruding into the nasal or naso-pharyngeal cavity. These may be more common than is supposed. They may be mistaken for nasal polyps. The occipital cephaloceles are the most frequent of all. They are situated either in or near the posterior fontanelle, or lower down under the occipital protuberance, where the hernial opening may be conjoined with the foramen magnum. Hernial protrusions from other sutures are much more rare, although they do occur in the greater fontanelle, in the squamous suture, or between the ethmoid and sphenoid bones at the base of the skull.

Cephalocele is uncommon, Trélat finding but 3 in 12,000 births, and Vines 1 in 5,000. It is said to be more common in females than in males, though Z. Lawrence, quoted by Erichsen ("Surgery," vol. ii., p. 378), collected 39 cases, 21 of which were males.

The tumors vary in size from that of a pea to that of a child's head. The occipital are always the largest, and are usually hydrocephaloceles. The sincipital tumors are, as a rule, small and simple encephaloceles. Meningoceles may exist in either place, but are more common behind. Hydrocephaloceles are rarely sincipital, owing to the positions and conformations of the ventricles, which are more apt to dilate posteriorly.

The occipital *hydrocephaloceles* are usually constricted at their base, often pedunculated, almost globular in form, and seldom attached by broad bases. They generally contain the dropsical posterior horns of the lateral ventricles or their fetal analogues. Those in the lower occipital region enclose the cerebellum and the hydropic fourth ventricle. In some of the largest hydrocephaloceles have been found a great part of the cerebrum, the cerebellum, the fourth ventricle, and the quadrigeminal bodies. The protruding cephalic parts are commonly of inferior or defective development, often difficult to recognize as brain substance, owing to cystoid degeneration and sclerosis (Huebner). P. Berger (*Revue de Chir.*, 1890, x., 269) reports an extirpation of an encephalocele and a case by a colleague (Périer) in which both specimens were carefully examined by Ranvier and Suchard, showing features not hitherto described. In both were found histologically a mixture of nervous elements of both cerebrum and cerebellum without lines of demarcation, and Berger regarded these tumors as forming a variety of central neuromata such as have been described by Virchow (tumors formed in the ventricles of subjects afflicted with congenital hydrocephalus). Berger proposes the term *encephalome* for this species of encephalocele. Sometimes the constriction at the hernial opening is so great that there is marked stasis of blood in the pia, which may lead even to extravasations. Occasionally these tumors present longitudinal constrictions caused by the venous plexus or by the falces of the dura. The quantity of fluid contents varies, but may reach two quarts. It has been found to be rich in albumin, with a specific gravity of 1.010–1.012.

The *meningoceles* of the occipital region are quite as large as the hydrocephaloceles, and similar in shape, while those of the sincipital and lateral areas of the skull are much smaller. One very large meningocele held fluid which had a specific gravity of 1.004, and contained a small quantity of albumin, uric acid, chloride of sodium, and biliary coloring matters (Heineke).

The *encephaloceles* are usually small tumors with broad bases, having a diameter as a rule between 1 and 3 cm., generally occupying a position at the root of the nose, and containing often, besides cerebral substance, a small quantity of subdural fluid.

Pathology.—There are several theories advanced to account for the origin of these congenital tumors. One is, that there is a limited ventricular dropsy, which by pressure at some certain circumscribed portion of the skull expands and separates the cranial bones and thus protrudes. From a hydrocephalocele thus formed an encephalocele may be produced later, by reabsorption of the dropsical fluid; or a meningocele, by a recession of the cerebral substance into the cranial cavity. The arguments against this hypothesis are, that there would scarcely be a circumscription of the dropsy as imagined, but rather a tendency to a general hydrocephalus; and, furthermore, Ackermann and Heineke have determined that there is a diminution, and not an increase, of intracranial pressure in cases of cephalocele.

A more probable theory as to the etiology of these tumors is, that they originate in the early embryological periods, when the cerebral vesicle and its fluid contents are in process of growth, and their osseous capsule is not yet developed. There is then an arrested or defective evolution of the cranial vault, as a result of which complete closure of the skull does not take place, and a circumscribed portion of the fetal brain vesicle protrudes. According to this hypothesis, hydrocephalocele would belong to an earlier stage of development, and encephalocele to a later, when the protruding portion of brain no longer exhibits the configuration of the fetal brain vesicle as it does in the former. In like manner, meningocele may originate either by the mere extrusion of the dura mater through pressure of the subdural fluid, or by the bursting of a hydrocephalocele, or it may be the remnant of a disorganized encephalocele. Meningocele might also spring from the cerebral vesicle in the earliest stages of development, as a mere membranous cyst without brain substance. Yet, if the defect in the skull were the only factor in the formation of these tumors, it would be difficult to understand why they are not present in every child in the open cranial spaces, the fontanelles. We are compelled, therefore, to recognize, as another factor in their causation, a general or partial hydrocephalus, either internal or external.

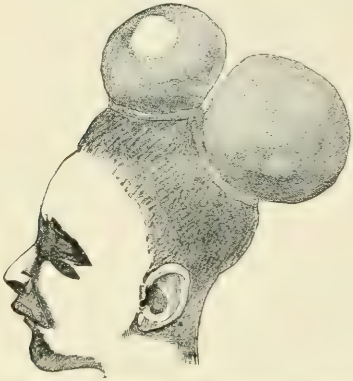
FIG. 809. Double Cephalocele, in Which the Anterior Tumor is Covered by the Skin, the Posterior by the Dura Mater. (After Taruffi.)

This conception of the embryological origin of cephaloceles is corroborated by the fact that most of them are found in front of and behind the head, in the median line, which is the most marked direction of growth of the cerebral vesicle; and that other defects and malformations of the skull, face, spine, feet, etc., are often observed in connection with these cases. Thus, striking departures from the normal shape of the skull are particularly noticeable in hydrocephalocele and the large meningoceles, where there is often asymmetry, thickening of the sutures, microcephalus, flattening from before backward, and sometimes hydrocephalus; while in the simpler tumors the skull presents, as a rule, a wholly normal configuration.

What may be the ultimate causes of these defects can only be surmised. Premature union of the meninges with the amnion, and injuries to the fetal head *in utero*, may sometimes be the occasion of their development. Benger (*loc. cit.*) reviews all the theories in detail (intracranial pressure from limited dropsy, arrest of fetal cranial development, fetal craniotabes) and believes himself that an encephalocele is a primitive protrusion of part of the brain previous to the formation of the cranial vault. He agrees with Fleischmann and Niemeyer that the cause of a simple encephalocele may lie in a hyperplasia of brain substance.

Lindfors occupies a whole number of the *Klin. Vorträge* (Leipsic, 1898, Nos. 222, 223) with a discussion of the history, etiology, and surgical treatment of congenital cerebral hernias, bringing the whole subject well up to date (April, 1898), and citing three full pages of literature. He believes there are many different forms and a variety of causes, that even within one class there may be special individual modifying causes. The etiology of hydrencephalocele is probably the same as that of hydrocephalus, but acting in a limited area. In other varieties, hydrocephalus, new growth, hygroma of meninges (Virchow), amniotic adhesions, rachitic condition of bones, may all have a place in the etiology of special cases.

Clinical Features.—The cutaneous surfaces of the cephaloceles are usually smooth, more or less distended, and sometimes very vascular. Occasionally they are excoriated, or present old cicatrices. Angiomata and lipomata have been described as forming upon cephaloceles (Larger, Ried). Hydrocephalocele and meningocele exhibit a distinct sensation of fluctuation, while the encephaloceles have more of a sensation of softness and elasticity, but also show fluctuation if surrounded by a sufficient quantity of fluid. When the coverings are thin, from great tension by fluid contents, these tumors may be translucent. They frequently pulsate synchronously with the pulse and respiratory movements; and their tension is often variable, as there may be a sinking of the tumor in sleep, and marked bulging out in the acts of crying or coughing. They may sometimes be diminished in size by pressure, which if moderate does no harm, but if great not infrequently produces symptoms of brain compression, such as vomiting, retardation of the pulse, unconsciousness, and convulsions. Pulsation is, as a rule, absent in meningocele and hydrocephalocele, but this naturally depends directly upon the size of the hernial opening in the skull, and the intercommunicability of the contents of the sac with those of the cranium; these tumors also show generally little variation during sleep, coughing, or crying, or upon the application of pressure, unless the hernial foramen is large. Symptoms depend to a great extent, too, upon the physiological value of parts protruded; and in cephaloceles such parts are often very different from their analogues in the normally developed brain. In the light of the recent discoveries in cerebral localization these cases might often afford very interesting results by careful study.

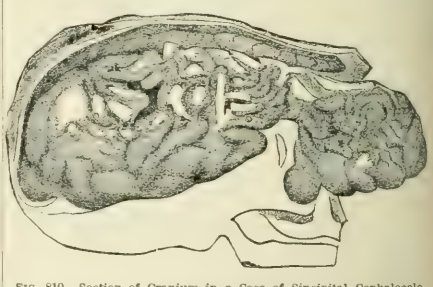
FIG. 810.—Section of Cranium in a Case of Sincipital Cephalocele. (After Vannoni.)

Prognosis.—Many children affected with meningocele or hydrocephalocele die before or during birth. Sometimes the tumor bursts during parturition. Those born living rarely last many years, partly on account of the imperfect conditions of their brains, and partly because the tumor often rapidly increases to such size, by the superaddition of cerebro-spinal fluid, that it bursts spontaneously, causing death either speedily, in coma or convulsions, or slowly, from a consecutive meningitis. Recovery after such evacuation of the tumor takes place but rarely. Death occurs usually in the first two or three years of life, but a few children with meningocele have attained the age of twelve, and even seventeen years.

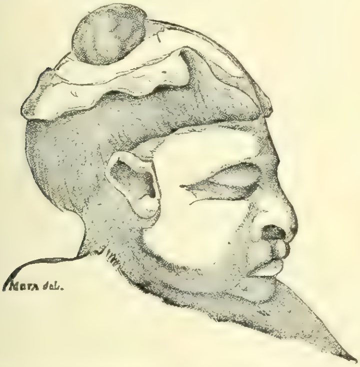

FIG. 811.—A Case Observed by Dr. Irving C. Rosse, of Washington, D. C.*

The encephaloceles being smaller and simpler than the varieties just mentioned, still-birth and rupture are less common in cases affected with them, although they do occur. As a rule, this class either grows slowly or remains stationary. Whatever disturbance is excited is due to disorder of brain function, but patients suffering from the frontal variety live longer and with fewer cerebral symptoms than those afflicted with the occipital variety. Children with occipital encephaloceles are generally idiots, whereas with the frontal or sincipital tumors they are more commonly of quite normal intelligence. Many have reached adult age.

Spontaneous recovery from encephalocele and meningocele has occurred, according to the observations of Wernher, Textor, von Bruns, and Held, by closure of the cranial defect and the complete isolation of the tumor as a cyst on the outside of the skull. Operative procedures have proved successful in some instances.

Diagnosis.—Every tumor of congenital origin situated along the median line of the head, in the region of the root of the nose or in the glabellar or occipital regions, should excite suspicion of a cephalocele; and defects or malformations in other parts of the skull or body would be corroborative evidence. The fact of its being congenital must first of all be determined; then its relation to the various cranial sutures. The diagnosis is easy when the tumor is in one of the situations that have been described, when there are pulsation and a sensation of fluctuation, when there is a change in tension during sleep or in crying, and when there is a recession of its contents into the skull upon pressure. If, at the same time with the recession of the brain substance or cerebro-spinal fluid, symptoms of irritation or compression of the brain develop, if there is an increase in the pulsatory or respiratory brain movements, and particularly if the edges of the hernial opening in the skull can be felt, a cephalocele is certainly present. But sometimes most of these pathognomonic symptoms are absent, and the diagnosis can be made only from the seat and history of the tumor. Although seldom necessary, a fine aseptic hypodermic needle may be introduced to determine the character of the contents and the presence or absence of an opening in the skull.

The recognition of these hernias in the occipital region is easiest, because other congenital tumors of similar form are of extreme rarity in this position; but dermoids, angiomata, and sarcomata of prenatal origin may have their seat at the nasal root, in the frontal region, or at the inner canthus of the eye, and thus lead to confusion. In the case of these latter, the mode of development must be carefully studied, and note taken of variations in tension, compressibility, and pulsation, and of the appearance of cerebral symptoms upon pressure. Angiomata exhibit pulsation and tension changes, and may be often completely compressed, but without brain symptoms or the discovery of an opening in the skull. Pulsation and compressibility are lacking in dermoid tumors. Cranial sarcomata which are congenital, or which appear shortly after birth, may present brain symptoms on pressure; there may also be an opening in the skull which pulsates; and finally these growths may have a similarity of feel, but they grow much more rapidly than cephaloceles, and usually are wanting in the more characteristic symptoms of the latter. The differentiation of the varieties of cephalocele can be made from the peculiarities that have already been described. In naso-pharyngeal varieties it is well to remember their occasionally close resemblance to nasal polypi.

Treatment.—The most difficult class to treat are the hydrocephaloceles, but measures can at least be taken to prevent sudden death by spontaneous rupture of the sac. This is still more important in meningocele and cephalocele if there be a rapid increase of fluid and tension, as a cure is possible in many of these cases. Equable pressure should be made by means of cotton batting and a bandage, care being taken not to produce brain symptoms by too strong compression. If the distention increases puncture should be made with a hypodermic needle, with antiseptic precautions, and the fluid slowly aspirated—all of it if the tumor be small, but only a portion in the case of large sacs. Then cover with aseptic cotton and continue the compression. Puncture may be repeated at appropri-

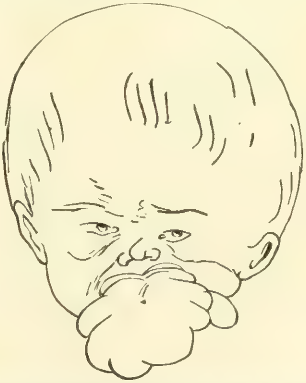

FIG. 812.—An Irregular Tumor Proceeding from the Cranial Cavity by a Large Opening Situated Immediately in Front of the Sphenoid, and Behind the Still Cartilaginous Ethmoid. Naso-pharyngeal cephalocele. (Virchow.)

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* The case shown here is that of an illegitimate male child of eight months. The tumor, about the size of a walnut, protruded from an opening in the right parietal bone just above and behind the protuberance. The child was club-footed, ectrodactylic, and had double harelip. Being unable to feed, it died after three days from inanition. The mesenteric glands were found to be enlarged.—I. C. R.

ate intervals. If rupture has already taken place, the antiseptic dressing and pressure bandage should nevertheless be applied. By this procedure rupture may be prevented, the tumor may be gradually diminished in size, and occasionally even dissipated. Youths or adults who are occasionally observed with stabile encephaloceles should wear protective plates properly curved, with bandages, and sometimes compression may be made use of, if it be deemed expedient to do anything, but great care is needed to avoid the production of brain symptoms. Puncture in simple encephaloceles is permissible only in case of continual augmentation in size—no other operative procedure is advisable. This is about all that can be done without risk. In many cases in which incisions have been made into these tumors, through a mistaken diagnosis, the result has been death from meningitis. Puncture and the injection of iodine have been fatal.

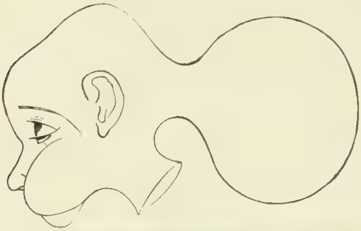
FIG. 813.—Posterior Hydrencephalocele. After Holmes.

Meningoceles are more amenable to treatment, as a rule, than the other forms of cephalocele. Occasional punctures, together with compression, have met frequently with good results. Little is to be expected from iodine injection, although Paget was successful with it in one instance. The stabile meningoceles should, as a rule, be let alone, because they communicate almost always with the cranial cavity. Annandale in one case ligatured the peduncle and removed the tumor, the child recovering completely in spite of an attack of measles. Thompson has also cured a case by ligation. Schatz cured a case by the gradual compression of a clamp applied to the sac. Sklifasowsky removed an occipital cephalocele from a nine-months child with a ligature, the result being successful The procedure is permissible in proper cases under strictly antiseptic precautions. Many operations in these cases have been undertaken since the inauguration of the new era of brain surgery, and much can now be achieved in the treatment of congenital cephaloceles, guided by the light of the latest discoveries in cerebral localization and by our improved technique in cranio-cerebral operations, which was formerly impossible. Fenger (*loc. cit.*) operated successfully on a nasal type, first removing the polypoid mass with the écraseur. There was free discharge of cerebrospinal fluid. The nostril was packed with iodoform gauze preparatory to radical operation to close the hollow peduncle. He then did an osteoplastic resection of the superior maxilla (as devised by von Langenbeck), and transfixed and ligatured the peduncle. Aspiration of the tumor for fluid had been twice negative. He considers in this class that extirpation should always be practised even if the tumor is small and causes no more disturbance than an ordinary polyp, as there is always danger of meningitis from accidental injury or surface inflammation. Preparatory operations are necessary, and these vary with the different situations in the nose.

Möller (*Deutsch. Zeitschr. f. Chir.*, 1898, xlviii., 23) has an article on the surgical treatment of hydrencephalocele, in which he says that the old rule of Heineke against operation has now been overthrown, since the day when von Bergmann openly advised radical operation wherever possible (1888). Möller cites de Ruyter's (von Bergmann's assistant) rules, as follows:

Meningocele should certainly be operated, because of possible ulcerations, because the tumor presents a point of lessened resistance in which a meningitis may originate, and because the patient is greatly burdened by the presence of the tumor.

Encephalocele should be operated unless it contains too large an amount of brain tissue. It usually holds a somewhat unimportant part of the brain, part of the occipital or frontal lobe.

Hydrencephalocele should not be operated because of its communication with a ventricle.

To combat this last rule of de Ruyter, Möller cites a case of successful operation on an occipital hydrencephalocele, where the tumor was nearly the size of the infant's head. The peduncle was solid, the lumen having been obliterated. Examination of the child one year after operation showed it to be in good condition and of apparently normal mental development.

Schmitz (*St. Petersburg. med. Woch.*, 1898, N. F., xv., 193) reviews the forms of cephalocele and methods of operation, giving his experience of seventeen cases. He concludes that the permanent results of operation are very unsatisfactory. Life is prolonged, but in the case of hydrocephalocele, the child dies of hydrocephalus, or remains hydrocephalic. This he says is also true of meningoceles which show any signs of hydrocephalus. If there be no hydrocephalus, the prognosis is much better. Schmitz thinks the prognosis is best for the pure encephaloceles or solid tumors. It is important to note whether the tumor remains of original size or is disposed to grow, and whether it grows slowly or rapidly. In the latter case we must assume increasing intracranial pressure, and we have therefore a hydrocephalocele, or such a type is developing from the original encephalocele. Another question concerning the advisability of operation relates to the contents of the tumor. If sincipital, the middle frontal convolution is involved, and we may feel justified in removing a small portion. No motor and little mental disturbance will result. In the occipital class there is usually cerebellar tissue (hemisphere) and less frequently parts of the occipital lobe, and no symptoms are likely to follow removal of small peripheral portions of the cerebellum. In case of large prolapsus of brain substance, excision should not be practised.

Berger (*loc. cit.*) believes radical operation to be justified in cases in which the tumor is growing and in which the prognosis is bad without interference.

Tilmann (*Berlin. klin. Woch.*, 1895, xxxii., 1055) says that the old methods of compression, puncture, iodine injections, and use of ligature are not now considered in the treatment of meningocele. Even if infection is avoided there is always danger of meningitis. He cites two cases of cephalocele operated at Bardeleben's clinic. The first was an occipital meningocele, the size of an apple, removed a few weeks after birth. The child developed normally. The tumor had a very small lumen and thick walls of œdematous fibrous tissue. The second case presented a congenital occipital meningocele the size of

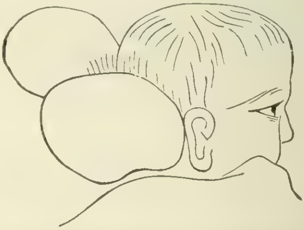
FIG. 814.—Tumor Divided in Two. (From Reali.)

the child's head. Operation was performed one day after birth because of insistence of the father. One litre of fluid was aspirated and the tumor sac then removed. There was improvement at first, but the child died on the twenty-third day with paralysis and convulsions. The case was one of meningocele with chronic internal hydrocephalus. He discusses fully methods of operation.

ACQUIRED CEPHALOCELE OR PSEUDO CEPHALOCELE.—Among the cephaloceles which originate subsequently to birth, through disease of the cranial bones or subcutaneous fractures, the most common is the pseudo-meningocele. This is observed almost exclusively in infancy or early youth, but, in very rare cases, sometimes in adults after healing of the superficial skull coverings in fractures. Conner* has written the best article upon pseudo-meningocele that is to be found in American literature. Under the name traumatic cephalhydrocele he describes 2 cases occurring in his own practice, and makes an analysis of 22 others collected from general literature; 19 of these were due to subcutaneous fractures of the skull, 2 to old gunshot wounds of the skull and membranes where the scalp had reunited, and 1 was the result of trephining; 17 of the cases were under three years of age. G. Vivien has collected 8 cases, and Thomas Smith (St. Barth. Hospital Reports, vol. xx.) reported 2, and described 20 analogous cases. All of Smith's were under sixteen years of age.

The history is usually that a child falls upon its head, and that, several hours or days after, a fluctuating swelling develops under the scalp, which may at first be diffuse, but later, as a rule, assumes the form of a sharply bounded cystic tumor. It may reach the size of the fist or be larger. It is over the injured spot, fluctuates, and often pulsates. There is sometimes a hardened border to the tumor. Occasionally, by firm pressure, the fluid may be made to recede more or less completely into the skull cavity, when the fractured bone may be felt. When this is not possible, the break may often be felt after puncture and evacuation of the tumor. In many of these cases puncture has shown the contents to be cerebro-spinal fluid. In post-mortem examinations which have been made, the fluid has been found to lie under the pericranium, lifting it with its outer coverings like a cystic sac; a cleft is observed in the bone, and one of the same size or smaller in the dura mater, through which the sac and subdural cavity communicate. Occasionally the cortex has been injured, and in recent cases there would be signs of softening and of laceration of the other membranes. In a case of Lucas, the pseudo-meningocele communicated with the open inferior horn of the left ventricle. Two or three cases may be mentioned in illustration of this traumatic form. Southam (*British Medical Journal*, May 12th, 1888) gives the details in the case of a male infant, aged six months, that fell downstairs and sustained a subcutaneous fracture in the right parieto-occipital region. Fourteen days later there was a swelling over the fracture, oval, soft, fluctuating, and pulsating. Moderate pressure was applied with a pad of lint and a bandage. In a month the swelling had disappeared and the child recovered. There was still a marked depression in the bone. Conner's first case was a boy twelve and a half years of age, who fell from a wagon, a wheel passing over his head. He was not unconscious, and walked into a house near by. There was a simple depressed fracture of the right half of the occipital bone, and a non-pulsating swelling over the fractured area, which he supposed to be due to extravasated blood. A week later, serum began to ooze from the nose, and there was puffiness of the right eyebrow. He punctured and drew off four ounces of a pale straw-colored fluid. The sac rapidly refilled, and four weeks later five ounces were removed. There were four subsequent tappings, the fluid withdrawn aggregating nineteen ounces. The specific gravity was 1.007; no albumin; sodium chloride, 6.6 parts per 1,000. The boy was never unconscious or delirious, but there were some insomnia and mental irritability, and the pulse ranged from 100 to 120. Conner's second case was a hydrocephalic and rachitic colored child about two years of age that fell a distance of five feet upon its head. There was no scalp wound, but a swelling appeared very quickly over the right parietal bone. In a few days it measured four and a half by three and a half inches, and exhibited pulsation and fluctuation. A radiating fracture could be felt through the tumor. No treatment was undertaken, and nine months after the accident the swelling had disappeared.

There are several facts which explain the almost exclusive prevalence of traumatic pseudo-meningocele in children. Possibly the flexibility of the skull gives a peculiar character to the fracture. The intracranial pressure is certainly relatively greater in children than in adults, and a more active secretion of cerebro-spinal fluid is probably another factor. The increase in subdural fluid may be due in part to the injury to the head, or in part to nutritive disturbance, rachitis, or some such thing, which does not give rise necessarily to a general hydrocephalus. The pouring out of the fluid, its augmented secretion, and the expansive power of the growing brain, all aid in preventing closure of the osseous fissure, and, indeed, may actually cause its enlargement, and even eversion of its edges. But pseudo-meningocele is not a constant result of subcutaneous fracture in childhood, and it is likely that various causes and conditions conduce to its formation.

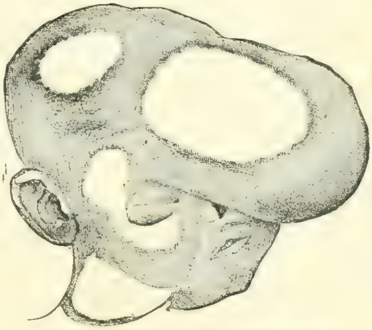

FIG. 815. Sincipital Cephalocele. (After Vannoni.)

There are not many observations as to the further course of traumatic pseudo-meningocele in children. Conner found that fifty per cent. of the cases collected by him died of meningo-encephalitis. In some patients the tumor remains unchanged in spite of frequent puncture, and in others it is cured by this means. Spontaneous retrogression may take place. The cleft in the skull generally remains open, and hence the prognosis is always relatively unfavorable. These cases are often of considerable forensic interest. Bayerthal (*Deutsch. med. Woch.*, 1898, xxiv., 37–58) relates the case of a man aged eighty-one years, with a pseudo-meningocele still persisting, due to a brick falling upon his head when he was nine months old. The man was always normal, except that he did not learn to walk until four years of age, and that he developed epilepsy at the age of seventy-nine years. This is the only recorded case of such long persistence of a pseudo-meningocele.

Pseudo-meningocele in adults has been observed several times after gunshot wounds of the skull, when the scalp wound has healed, and once after recovery with defect of bone from trephining. Vivien mentions three such cases. As a result of subcutaneous fracture in adults it has apparently not been observed, and, if it occurs, must be extraordinarily rare.

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* Phineas S. Conner: American Journal of the Medical Sciences, vol. lxxxviii., 1884, page 103.

Pseudo-cephalocele sometimes results from syphilitic or tuberculous caries of the skull and perforation of the dura mater, and from complicated fractures accompanied with prolapsus cerebri. Such cases have been reported by Bennett, Tavignot, Bryk, Podrazki, Spring, Hawkins, Talko, Bruns, and Kusmin. In one case only did the dura mater protrude.

These tumors vary from two to five inches in diameter, and are usually of a soft, elastic consistence. The skin over them is either smooth, glossy, and pale red, or inflamed, indurated, and presenting fistulous openings. Sometimes there are pulsation and fluctuation. Dizziness, retardation of the pulse, and even unconsciousness can, as a rule, be produced by pressure upon these tumors with the finger. Partial replacement may be brought about by compression, and in one case there was complete return of the hernia by gradual pressure. When the brain has protruded, this was doubtless due in many cases to the formation of cerebral abscess or to collections of pus in the cavity of the skull; in some cases, probably to œdema or encephalitis with tumefaction of the brain in the neighborhood of the diseased or injured skull.

Treatment.—In pseudo-meningocele continuous and equable pressure should be employed, when practicable, but this should be done early. If the tumor is large and tends to increase in size, operative interference is allowable, and this is best carried out according to the methods described by von Bergmann below. Strict antiseptic precautions should be observed, and a compress subsequently applied. Irritative injections are not advisable. If the opening in the skull remains patent, it is well to keep it shielded by a plate and bandage for the prevention of a renewal of the tumor or injury to the brain. Tonics, nutritious diet, and lime preparations are indicated.

Other forms of pseudo-cephalocele are treated according to the nature of the bone disease or injury. In suppurative processes we must be on the lookout for pus deposits in the brain or skull cavity, and remove them, if feasible, with careful asepsis. It is best not to operate on the prolapsed brain itself, but in this we must be governed by what we have recently learned with regard to the physiological value of the different convolutions. Hitherto such heroic measures have been carried out usually as a result of error in diagnosis, and in these cases death has followed from meningitis, encephalitis, or hemorrhage. Compression should naturally be resorted to in these cases only when there are no symptoms of inflammation or suppuration. In the rare pseudo-cephaloceles of adults we may cautiously puncture and make use of the compress, but we should always be on the lookout for symptoms of inflammation and abscess.

Bayenthal (*loc. cit.*) advances the singular theory that the presence of a pseudo-meningocele may be of *advantage* to the patient as a safety valve for increased intracranial pressure, and that it might be more advantageous to *enlarge* it, than to remove it, in cases showing cortical irritation.

Von Bergmann (on "Cephalhydrocele Traumatica," *St. Petersburg. med. Woch.*, 1897, N. F., xiv., 61) says that in these cases he always presupposes a fracture of the skull—in the majority of the cases of the lateral aspects of the skull—the lined fractures being vertical. The interval often observed between the bones in such cases is doubtless due to subsequent absorption. A laceration of the dura has always been found at autopsy. He considers compression of service only in a few cases, and only when applied early. Puncture is successful in a few; but meningitis is to be feared. In 33 cases of Rahm, where puncture was employed, 6 were cured and 9 died. Of 3 cases treated by puncture and iodine, 2 died and 1 recovered with prolapsus cerebri. Two cases treated by incision and drainage died. He cites Krönlein's two cases, in which the sac was removed and drainage employed. Both recovered. One had to wear a plate, and in the other epileptic convulsions returned seven to eight months after operation. Von Bergmann concludes as follows:

1. Puncture should not be practised. Injections with iodine are still more inadvisable.
2. Compression should first be tried (with compress and bandage or with a plate). If the tumor is thereby kept small and flat, radical operation can be delayed.
3. If the tumor increases in size, the method of Slajmer and Dembrowski is simple and less dangerous than the method of Krönlein. This consists of making a flap of skin, periosteum and bone to cover the defect in the skull, first emptying the sac and dissecting it away from the edge of the bone.

Frederick Peterson.

BRAIN: CEREBELLAR DISEASE.—An etiological factor with specific predilection for the cerebellar tissue does not exist. Whatever causes disease of other organs and tissues of the body, produces occasionally also cerebellar lesions. Chronic purulent otitis media is of particular etiological significance; cerebellar abscess, a common affection of the cerebellum, is one of its frequent complications.

Prenatal intrauterine and intrapartum accidents and mishaps may occasionally lead to disease of the cerebellum, although this occurs more rarely here than in the other parts of the nervous system.

Ataxie héréditaire cerebelleuse (Marie, Nonné) is believed to be a hereditary disease of the cerebellum; the final proof that the cerebellum only and primarily is the cause and seat of this disorder is, however, still wanting.

Cases of congenital atrophies and scleroses of the cerebellum are on record. Their etiological explanation is still very obscure. For some of these cases, possible intrauterine inflammations or traumatisms or intrapartum accidents may furnish a probable etiology, analogous to similar results wrought by the same factors on the brain, and occasionally on the cord.

Specific acute infectious diseases like poliomyelitis and poliencephalitis do not occur in the cerebellum.

If any damage is done to the cerebellum in the course of acute infectious diseases, it has not been recorded.

The chronic infectious diseases—syphilis and tuberculosis—are quite frequent causes of cerebellar disease. Neither appears to injure the cerebellum directly, and the metasyphilitic toxins, of so great an etiological importance for the brain and cord, show no affinity for the cerebellar tissue.

The cerebellar degenerations found, in cases of tabes, are manifestly secondary to the primary disease.

Solitary tubercles are frequently found in the cerebellum, and localized basal tuberculous meningitis may occasionally damage the cerebellum.

Formation of gummatous tumors is apparently rarer than that of the tuberculous variety, and the syphilitic meningitis, in the vicinity of the cerebellum, is more frequent than the tuberculous.

Finally, it is to be remembered that syphilis, by injuring the blood-vessels, is occasionally at the bottom of cerebellar mischief. It is true, this is vastly less often the case here than in the brain or cord, partly on account of causes explained further on.

Exogenous intoxications do not seem to harm the cerebellum, although the picture of acute alcoholism is believed to be caused by cerebellar disturbance.

General pathological conditions (anæmias, diabetes, carcinosis, etc.) do not directly influence the cerebellum.

Arterio-capillary fibrosis is the only general state of etiological significance.

Hemorrhages, embolisms, and thromboses of cerebellar blood-vessels are not very frequent.

Embolism of cerebellar arteries is apparently a great rarity. This is in part due to the anatomical peculiarities of the cerebellar vascular supply. All three cerebellar arteries (arteria cerebelli inferior posterior, arteria cerebelli inferior anterior, and arteria cerebelli superior) leave their principal branches at a right angle, and therefore an embolus will be carried away by the circulation through the wider basilar artery, and will be finally lodged in the arteria cerebri posterior.

Thromboses of cerebellar arteries are quite rare; occasionally thromboses of the vertebral arteries may lead to patches of softening in the cerebellar hemispheres.

Hemorrhages of cerebellar blood-vessels are also not very frequent.

The cerebellar arteries are very much smaller than the cerebral, and the only larger artery, the arteria corporis dentati, is accordingly the one that is most frequently ruptured.

Some cases of acquired cerebellar atrophies and scleroses are perhaps interpretable in a similar way on an arteriosclerotic basis, as are analogous conditions of the cord or brain.

Inflammations of the cerebellar tissue are occasional findings, but apparently most of the time they are secondary purulent infections.

The autochthonous and metastatic tumors of the cerebellum have here the same causes as in the other parts of the body.

Disease of the bones, meninges, and other contiguous tissues, and various external injuries, lead to a variety of secondary pathological states of the cerebellum.

Symptoms.—About twenty years ago, Nothnagel wrote in the classical monograph embodying the clinical thought of that time that there is more diversity of opinion and controversy concerning the symptomatology of diseases of the cerebellum than of any other part of the brain.

At present there are still some who have this opinion, and occasionally reports are heard of cases of disease of the cerebellum "without symptoms"; in other words, the cerebellum is still to be classed under the "silent areas." Increased clinical minuteness diminishes considerably, however, the number of cases of disease of the cerebellum "without symptoms."

At an earlier date, experimental methods were employed to clear up this question, and indeed greater unanimity was reached. The results obtained by experimental physiologists (Flourens, Magendie, Weir Mitchell, Luciani, Ferrier, and Turner), by their efforts to ascertain the symptoms of irritation and paralysis of this part of the nervous system, furnish a safe basis for the construction of the symptomatological picture. However, a great many points of the symptomatology are still under discussion, because focal and distant symptoms are not kept sufficiently asunder as yet.

The symptoms of cerebellar disease that may be termed focal evidently do not depend upon the nature of the causative lesions. Tumors, abscesses, softenings, degenerations, etc., will necessarily give symptoms more or less identical of irritation or paralysis of function.

Differences of degree only and not of kind are frequently observed. These are dependent upon the character of the lesion, whether slow or rapid, destructive or stationary.

Territorial variations of the lesions do not seem to exert any considerable influence.

The point particularly dwelt upon by Nothnagel, that only a lesion of the vermis leads to symptoms, while lesions of the hemispheres have no clinical manifestations, has not been corroborated as fully as it was originally claimed.

All of the foregoing will be better understood when a few cardinal points of the physiology and pathology of the cerebellum, about which all clinicians and experimental physiologists seem to agree, are borne in mind. These points are, first, the fact of the anatomical and physiological homogeneity of the cerebellum.

Microscopically, the structure of the cerebellar hemispheres is found to be the same all over, and on that basis, as well as on clinical and experimental evidence, physiological identity is conjectured. Thus it is evident that one part can easily take up the function of the other.

It is further established by clinical and experimental evidence that the functions of the cerebellum are taken up by other parts of the nervous system, particularly by the somæsthetic cortical areas (Luciani).

The above-mentioned dissensions are easily understood, when one considers that the experimental physiologists observe the animal throughout the whole time of the disease, see it, as it were, during the flourishing period of the symptoms, and in the period when, through establishment of direct or indirect compensation, a good part of the symptoms are disguised or obscured; and that, on the other hand, clinical observations most of the time extend over a limited period only, and by some observers cases are seen with fully established compensation, and by others cases more or less compensated or not at all.

After these remarks it is safe to state that the symptoms of disease of the cerebellum, no matter what lesion gives rise to them, are symptoms referable to disorder of the equilibration, regulation and adjustment of the voluntary movements, and are comprised in the name of cerebellar ataxia.

Luciani attempted to analyze this compound phenomenon and claims that it is composed of the following three elements: asthenia, atonia, and astasia. All these three elements give rise to a disorder of motor function that he calls motor dysmetry.

The point to which the compensation has progressed, necessarily influences the intensity of the ataxia. Not all agree, however, with Luciani, and particularly the asthenia and the atonia are denied by others.

In addition to this cardinal and direct or focal symptom of disease of the cerebellum, a number of symptoms are described in cases of cerebellar disease, the greatest part of which can manifestly not be taken as focal but must be designated as indirect or distant symptoms.

The principal focal symptom of cerebellar disease is the cerebellar ataxia. This ataxia manifests itself on the patient, first by disturbance of the general equilibrium in the form of swaying that becomes markedly increased when the eyes are closed and the feet put together. The gait designated as cerebellar gait, and according to the French (démarche d'ivresse) gait of drunkenness, is very much altered; the patient progresses in a zigzag line, the individual steps are irregular and unequal, the feet are lifted unduly high from the ground and brought down heel first with undue force.

These evidences of static and locomotor ataxia are differentiated from the same symptoms in cases of genuine tabes by the fact that patients with cerebellar disease show little or nothing of this ataxia when in bed.

This disorder of the muscular apparatus is in most cases evidenced exclusively or predominantly in the lower extremities.

A group of motor phenomena, called forced attitudes and forced movements, form the focal symptom next in importance. The head and trunk of the patient are either permanently deviated toward one side, or the patient performs queer rotatory movements around his own axis toward one side or the other—movements evidently not purposeful, and having clearly a character of forced propensity (manège movements).

The side toward which the permanent deviation or the forced movement is directed is differently reported by different observers. According to some, the head or the trunk deviates or the patient moves toward the side of the lesion; according to others, toward the opposite side; and according to still others, the passive deviation is toward the opposite side, while the active movements are toward the side of the lesion.

Another explanation of this diversity is based on the fact that lesions are either irritative or paralyzing; irritative lesions are thought to produce forced *movements* toward the same side, and paralyzing lesions forced *attitudes* toward the opposite side.

It is otherwise stated that forced movements and forced attitudes are dependent upon the situation of the lesion, and they are then interpreted as focal symptoms of the cerebellar peduncles, particularly of the middle ones.

The forced attitudes are clinically more frequently observed than the forced movements. A good illustration of a forced attitude is given in the accompanying picture of a patient in whom a tumor of the right cerebellar hemisphere was found, in which the deviation toward the same side is seen when the patient is in a reclining position, and more marked when she is standing (Fig. 817).

The two symptoms already named, *i.e.*, the cerebellar ataxia and the forced movements and attitudes, are the cardinal focal symptoms of cerebellar disease. But in almost every case there are additional symptoms recorded; some evidently not focal, others mooted as to their localizing significance, which are discussed seriatim below.

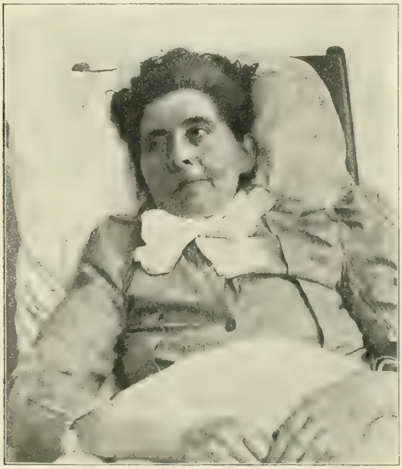


FIG. 816.—Case of Cerebellar Tumor, Showing Peripheral Facial Palsy.

Motor Symptoms: The upper extremities do not always escape the characteristic motor disorder. Here the ataxia is not so marked, but is often replaced by atactiform tremors and unsteadiness, occasionally simulating the intentional variety. The head may show similar motor unsteadiness, although rarely.

Localized unilateral and generalized muscular spasms, with and without loss of consciousness, are frequently mentioned, and by most observers are interpreted as distant symptoms.

Motor paralysis sensu strictiori is occasionally observed. Hemiplegias, paralysis of one-half of the body, are frequently mentioned in older histories of cerebellar cases. Here, too, the side upon which the paralysis occurs is not uniformly named; at one time the paralysis was homo-, at another heterolateral to the cerebellar lesion.

In view of the fact that experimental evidence has proven the homolateral influence of the cerebellum, it is to be assumed that hemiplegic symptoms are dependent upon encroachment of the lesion upon the pyramidal tracts, and not upon lesion of the cerebellar tissue proper. This is well illustrated by the accompanying photograph (Plate XIV.), which represents a case of tumor of the cerebellum in which the observed left-sided hemiplegia, which was produced, as can be easily seen from the photograph, by pressure upon the left-sided pyramidal tract, gave rise to diagnostic difficulties.

Various disorders of the ocular musculature, nystagmus, strabismus, ptosis, paralysis of individual ocular muscles or muscle groups, are also frequently mentioned. The greatest part of these symptoms are evidently due to pressure upon the corpora quadrigemina or oculomotor nuclei; but some of them must necessarily be taken as focal symptoms.

Experimentally, deviations of one or the other eye toward the same or the opposite side of the lesion were frequently ascertained.

The facial musculature is also frequently reported to have suffered. Occasionally this disturbance is only slight and transient, and probably of a nature similar to the motor disturbance of other muscles—*i.e.*, a cerebellar motor dysmetry; but most of the time it is due to compression of the adjacent seventh nerve. It is then a paralysis of the peripheral type, involving all the three branches and showing more or less disturbance of the electrical reaction. This is well illustrated in the accompanying photograph (Fig. 816).

The motor portion of the fifth nerve is sometimes found defective, evidently through pressure upon the peripheral course of the nerve.

In the sensory sphere no symptoms directly referable to the cerebellum are observed.

The sensibilities (tactile, algesic, thermal and kinæsthetic) are mostly unaltered. If sensory disturbances are found, as in a case of cerebellar abscess lately observed by the writer, they are easily traced to the spreading of the disease into the sensory pathways.

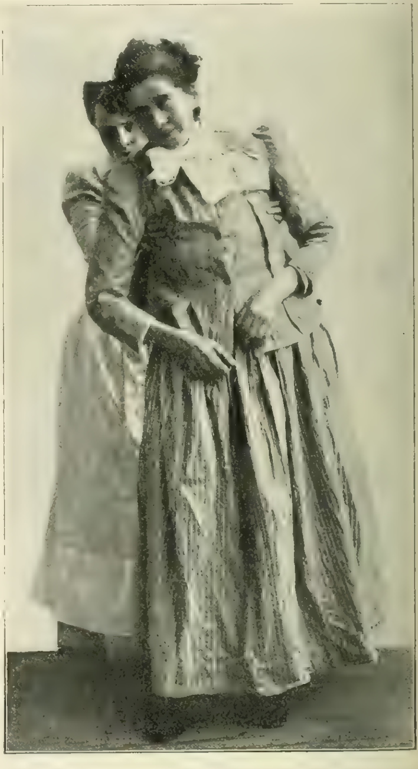
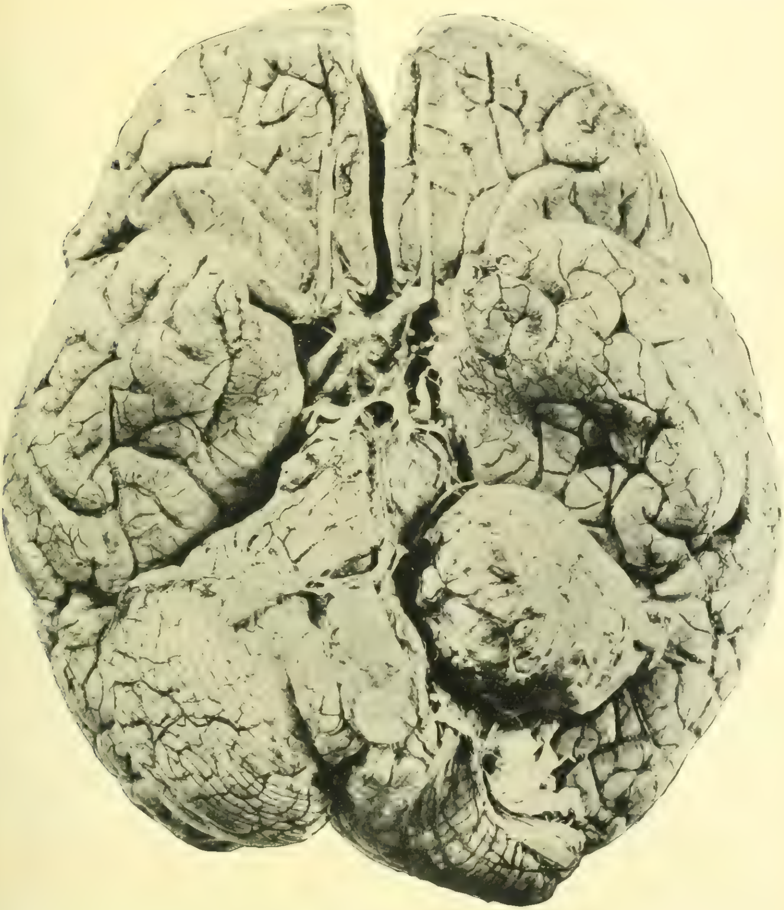


FIG. 817.—Case of Cerebellar Tumor, Showing Hemiplegia and Deviation.

Of the special senses sight and smell are frequently found impaired. Choked disc and optic atrophy are frequent and early accompaniments of compressing lesions



TUMOR OF THE CEREBELLUM

of the cerebellum. The old belief, however, that the cerebellum is in any physiological or anatomical connection with the visual centres, has long since been discarded. Similarly, anosmia, the loss of sense of smell, is not a focal symptom, but is dependent upon the pressure of hydrocephalic fluid, a frequent consequence of cerebellar disease, upon the olfactory bulbs.

The other cranial nerves may occasionally suffer indirectly.

About the state of the tonus of the muscles, the reports are almost diametrically opposite. According to some there is a normal tonus or even a hypertonia; according to others a unilateral or bilateral hypotomia; and according to still others there is at one time some rigidity, at another flaccidity.

In keeping with this, the reports about the reflexes, particularly the knee reflexes, are equally contradictory. They are reported to be present or exaggerated, or absent or diminished. Jackson and others report variability of the findings, and I have found it so in the patient whose picture is here reproduced, and whose tonus and reflexes were frequently examined.

Disordered trophic functions are reported by the experimental physiologists. But such symptoms have not been ascertained clinically. Occasionally the pes cavus is mentioned in this connection, but this is evidently the result of the static ataxia.

Visceral functions are rarely disturbed. Control of the sphincters is damaged only when the state of consciousness is interfered with. In this connection it is well to draw attention to the symptom complex that the French call syndrôme bulbo-protuberantielle — which consists of attacks of bradycardia and Cheyne-Stokes respiration.

These symptoms are evidently referable to pressure on the medulla, and will occur in any lesion in this neighborhood. The same may be said of the occasionally observed glycosuria and polyuria.

The mental functions are primarily not altered in cerebellar disease, and the old conception of the intimate connection of the cerebellum with the sexual instinct is without foundation.

The speech is frequently altered. The disturbance is of the dysarthric type, commonly called cerebellar dysarthria, and occasionally reminds one strongly of the syllabic speech.

Diagnosis.—The diagnosis of disease of the cerebellum is made without difficulty when the focal symptoms are pronounced. Frequently, however, the picture is considerably obscured by a number of distant symptoms or by compensation. *Joseph Fraenkel.*

BRAIN: CEREBRAL HEMORRHAGE.—Etiology.—The most frequent cause of non-traumatic cerebral hemorrhage is the occurrence of miliary aneurisms in the vessels of the brain. These aneurisms are 0.1–1 mm. in size and are found with extreme rarity in other organs. Charcot and Bouchard, who were the first to recognize them as the cause of hemorrhage, regard them as due to chronic periarteritis, which leads to an excessive proliferation of nuclei in the lymphatic sheaths and walls of the vessels, and sometimes to atrophy and disappearance of the muscular coat. These writers believe that the implication of the tunica intima, which is always present in such cases, is secondary to the affection of the outer walls. Almost all the more recent writers attach the chief importance to a primary affection of the tunica media. According to Roth, the intima is first attacked by waxy degeneration. Roth states that, in the beginning, we find diffuse cylindrical dilatation of the vessel, then there is degeneration of the muscular coat, occasionally of a waxy character. Next, all three layers of the vessel undergo aneurismal dilatation, and finally the intima and adventitia become thickened in order to compensate for the atrophy of the media.

Löwenfeld claims that various vascular changes may lead to rupture, viz., simple atrophy, fatty and granular degeneration or ordinary atheroma. There is very little doubt, however, that these views obtain, if at all, only in exceptional cases.

Miliary aneurisms are always very minute, and sometimes cannot be seen without the aid of a lens. Charcot and Bouchard noticed that they manifested a predilection for certain parts of the brain, being found with diminishing frequency in the following regions: optic thalamus, corpus striatum, cerebral cortex, pons Varolii, cerebellum, centrum ovale, peduncles, and medulla oblongata. In the very large majority of cases they are situated in the corpus striatum and optic thalamus, thus explaining the great preponderance of hemorrhages in this locality.

It has long been thought (and many clinicians and pathologists hold this view at the present time) that atheroma of the cerebral vessels is one of the main causes of cerebral hemorrhage. But this view is erroneous. Atheroma of the brain is confined usually to the arteries of the circle of Willis, and it is not uncommon to find these vessels as rigid and unyielding as pipe stems, without a trace of hemorrhage in the brain. In rare cases, even the vessels of the pia mater have been found to be exquisitely atheromatous, although no vascular rupture had occurred. On the other hand, it is not uncommon to find extensive hemorrhage, although atheroma of the vessels is entirely absent or very slight.

Age is an important factor in causation, the large majority of cases occurring after the age of forty-five years. But cases are not very infrequent at an earlier period, and they may also occur in infancy and childhood. Billard found a clot in the left corpus striatum in an infant three days old.

Heredity also appears sometimes to play a certain part in etiology, but it acts by inducing the development of miliary aneurisms, and not by giving rise to any defect in the cerebral tissues proper.

The disease also occurs quite frequently, during the course of Bright's disease, associated with hypertrophy of the heart without valvular lesion. It has been supposed that the cardiac hypertrophy and consequent increased arterial pressure are the active factors in this condition, but it is more probable that they act only as exciting causes, the real cause being found in the changes in the walls of the vessels (arteriosclerosis), which constitute an integral part of Bright's disease.

In scurvy, leukæmia, hæmophilia, and severe infectious diseases, minute cerebral hemorrhages may occur as the result of the nutritive changes induced in the walls of the vessels, but these will not be considered in this article.

Violent muscular strain, mental excitement, cold baths, etc., are also adduced as causes, but they prove efficient only if a lesion of the vessels is present. They probably act by causing active or passive cerebral congestion.

The large majority of cases occur in the male sex, the predisposing and exciting causes being more frequent in males than in females.

Pathological Anatomy.—If the patient dies soon after the occurrence of a cerebral hemorrhage, a soft, black clot is found, which can be readily removed from its cavity, and is usually mixed with shreds of brain tissue. The surrounding tissues are irregularly torn, and are softened and blood-stained for some distance around the clot. Very little fluid blood is present. The size of the clot varies from a minute speck (capillary hemorrhages) to a mass of enormous size, which may occupy a considerable portion of one lobe. In the latter event the blood usually ruptures into the lateral ventricle, may then pass into the opposite lateral ventricle, and also force its way through the third into the fourth ventricle. More rarely the hemorrhage breaks through the cortex and appears under the pia mater, usually upon the convexity. When the hemorrhage is large in amount, pressure effects are distinctly perceptible. The convolutions may be flattened, the falx cerebri pushed forcibly toward the opposite side of the brain, and even the nerves flattened at the base of the brain. In such cases the cerebral tissues are usually very dry.

If the loose clot is gently removed and the tissues slowly moved to and fro under water in order to remove the more adherent shreds, we shall usually be able to find the artery upon which the ruptured miliary aneurism (sometimes more than one) is situated.

After a variable period, depending chiefly upon the size of the clot, the latter begins to contract, finally breaks down, as it does in other localities, and absorption then begins. The extent to which this occurs varies in different cases. Sometimes the absorption is complete and perhaps nothing will be left at the site of the hemorrhage but a narrow, waxy, yellowish cicatrix, which contains a variable number of hæmatoidin crystals. The latter may also be scattered through the surrounding tissues, giving them a reddish-yellow color. In other cases the serum is not absorbed, and a cavity remains which may be lined with a delicate cyst wall. After the lapse of time it often becomes difficult, sometimes impossible, to distinguish these cysts from the remains of spots of softening. (Fig. 2, Plate XV.)

The changes described run their course in a short time. The clot remains soft for three or four days; absorption then becomes active and reaches its maximum toward the close of the second week. If absorption is not complete, the cavity contains serum by the twentieth day, and the cyst wall is fully formed in from four to six weeks.

Hemorrhages within the region of the pyramidal tracts, in any part of their course (and also those in the motor regions of the cortex), give rise to secondary descending degeneration, which extends down through the crus, pons, and medulla into the antero-lateral column of the opposite side of the spinal cord. In very rare cases the degeneration finally extends into the anterior gray horns of the cord.

Among twenty cases of descending degeneration of the spinal cord due to unilateral lesions of the brain, Pitres found four cases in which the degeneration was present in both lateral columns, though more markedly on the side opposite to the cerebral lesion. He attributes this phenomenon to very incomplete decussation of the pyramidal tracts in the medulla oblongata—the variability of which has been clearly demonstrated by Flechsig.

After hemorrhages into the occipital lobe secondary degeneration is found in the optic radiations and, at a much later period, in the external geniculate body, pulvinar, and anterior corpora quadrigemina. After the lapse of years this degeneration may involve the optic tract and nerve.

After hemorrhage into the second or the third frontal convolution we find degeneration of the dorsal bundle of the lenticulo-striate section of the internal capsule. This is followed by degeneration of the median segment of the cerebral peduncle, of the fibres to the median nucleus of the optic thalamus, and of the anterior portion of the lateral nucleus of the same ganglion.

After hemorrhage into the temporal convolutions degeneration of the most lateral portion of the peduncle has been observed in several cases.

After large hemorrhages into the tegmentum of the pons, secondary degeneration of the fillet takes place, not alone in an ascending but also in a descending direction. This extends to the nuclei of the posterior columns on the opposite side after the lapse of years, and the ganglion cells there undergo atrophy.

Almost all cases of old hemorrhage which have come under our observation on the post-mortem table have exhibited, irrespective of the site of the lesion, an atrophy of the brain. This is observed throughout the entire cerebral hemisphere on the side of the hemorrhage, and in the opposite hemisphere of the cerebellum. The atrophy of the latter is proportionately less marked than that of the cerebrum, but it appears to affect all parts alike. The cause of this phenomenon is obscure, but it is due probably to partial disuse of the structures implicated.

Symptomatology.—In the majority of cases there are no precursory manifestations of this disease. When they are present, they consist of vertigo, headache, ringing in the ears, general mental inertia, occasional lapses of memory, and defective speech. Sometimes slight numbness and a feeling of weakness may be felt upon one side of the body. The latter symptoms are generally dependent on a slight hemorrhage which has already occurred. The other prodromal symptoms are supposed to be due to congestion of the brain.

As a rule, however, the symptoms begin quite suddenly. In a considerable proportion of cases the attack develops during sleep, the patient going to bed in his usual condition of health and awaking in the morning to find himself paralyzed on one side of the body. When the attack occurs during waking hours, the patient generally experiences a strange sensation in the head and an increasing feeling of numbness and weakness on one side. This is followed rapidly by loss of power on that side, and the patient, if standing, falls to the ground, and in a certain proportion of cases becomes unconscious. It must be remembered, however, that a large number of patients retain their consciousness throughout the entire seizure. Thus it has been noticed that even twenty-four hours have elapsed from the onset of the symptoms to the development of complete hemiplegia and aphasia, the patient retaining consciousness and the control of his mental faculties during this entire period. The disturbance of consciousness in different attacks presents all possible grades from this condition to complete and profound coma.

In the most severe cases the patient lies motionless, with a turgid, sometimes livid face, the pupils varying but usually presenting no characteristic appearance, the cheeks flaccid and flapping loosely with respiration. The pulse is usually slow, full, and hard; the arteries of the neck pulsate visibly. Respiration is usually slow, labored, and attended with stertor; sometimes Cheyne-Stokes respiration is observed and is generally of fatal import. All the limbs may be in a condition of complete resolution, but more commonly the non-paralyzed side manifests a slight rigidity.

A not infrequent symptom of the apoplectic seizure is the so called conjugate deviation of the eyes and head. Both eyes are usually turned away from the paralyzed side, "as if looking toward the site of the lesion." Nystagmus movements may be noticed at times, but the axes of the eyes are not directed beyond the median line. The head is also turned in the same direction as the eyes, and offers distinct resistance when an attempt is made to restore it to the normal position. In extremely rare cases this symptom has been observed in attacks of cerebral hemorrhage unattended with loss of consciousness.

This peculiar phenomenon is usually noticed when the hemorrhage occurs in the parietal lobe (especially near the inferior parietal lobule), although it is also observed at times when other parts of the brain are implicated. According to Hughlings Jackson, conjugate deviation is of sinister prognostic import with regard to the recovery of the paralysis.

When the hemorrhage ruptures into the ventricles, or through the cortex beneath the pia mater, contractures or convulsions are frequently noticed. Pitres states that this symptom depends upon the point of rupture of the hemorrhage into the ventricle, and is produced only when the fronto-parietal fibres are involved by the lesion.

It has been stated that severe hemorrhages are attended invariably by an initial depression of temperature (one-fourth to one-half hour after the beginning of the seizure), followed in a few hours by a rapid rise, which continues until death in fatal cases, and subsides after a few days in the non-fatal cases. In some instances the temperature may rise from the very beginning, even though the disease has a rapidly fatal termination.

The cutaneous and tendon reflexes are usually abolished or greatly diminished during the period of coma. But this condition soon gives place to an increase of reflex excitability, with the exception of the cremaster and abdominal reflexes, which are found to be diminished.

As a general rule, the patient slowly rallies from the comatose condition, consciousness being restored usually in a period varying from an hour or more to a couple of

EXPLANATION OF PLATE XV.

EXPLANATION OF PLATE XV.

FIG. 1.—"The inner surface of the dura mater (right half) is covered with a pseudo-membrane which is colored a pale red in some parts, a dark red in others, and which clings firmly to the dura. On the left side there is presented an irregularly shaped yellowish-green deposit which rests upon an older layer of organized exuded material of a dark red color and infiltrated with blood. The explanation of these conditions is this: An infectious fibrino-purulent inflammation has, in this case, been grafted upon an older proliferative process, a complication which is observed only in rare instances. The pseudo-membrane, which is applied quite uniformly over the inner surface of the dura mater, is composed of a fibrous connective tissue which in some parts is rich in cells and everywhere is liberally supplied with blood-vessels (pachymeningitis vasculosa). In many places throughout the layers of newly formed tissue there may be seen hemorrhagic exudations, some of older and others of more recent date. It is safe to assume that these hemorrhages have come from the imperfectly developed new blood vessels, through a process of diapedesis." (Bollinger.)

FIG. 2.—*Apoplexy of the Right Hemisphere of the Brain* (*nucleus caudatus and nucleus lentiformis; capsula interna*). "In the right cerebral hemisphere, at a point corresponding to the location of the nucleus lentiformis, and extending from this outward as far as to the capsula interna, is an irregularly shaped cavity, somewhat larger than an English walnut, which is filled with dark, reddish-brown masses of clotted blood. Its walls in some places show a rusty red discoloration. Some bloody serum is present in the right lateral ventricle. The rest of the cerebral parenchyma is tough, the brain as a whole being atrophic (it weighs 1,220 gm.). The large arteries at the base of the brain are in a condition of marked atheromatous degeneration; the arteria pro fossa Sylvii is obliterated.

"Among the other pathological conditions found in this woman, who was sixty-nine years of age, the following may be mentioned: Chronic interstitial nephritis and hypertrophy of the heart (both ventricles), which weighed 475 gm. (the normal weight being from 250 to 300 gm.)." (Bollinger.)

PLATE XV.

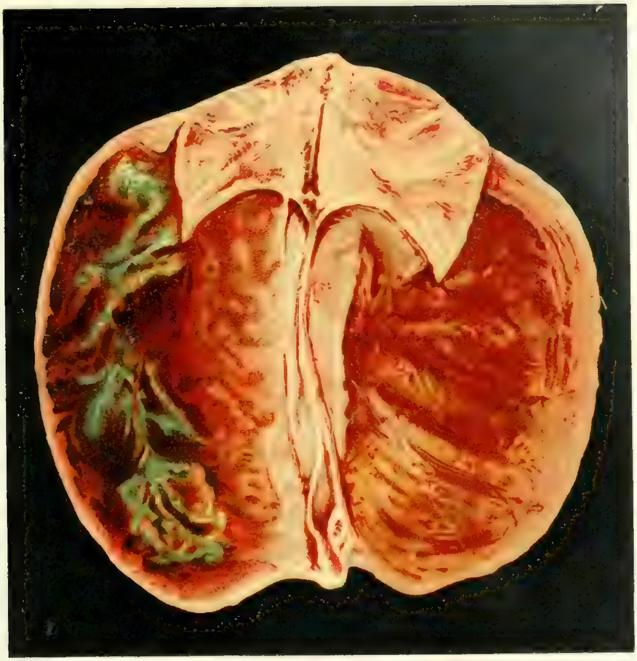


FIG. 1

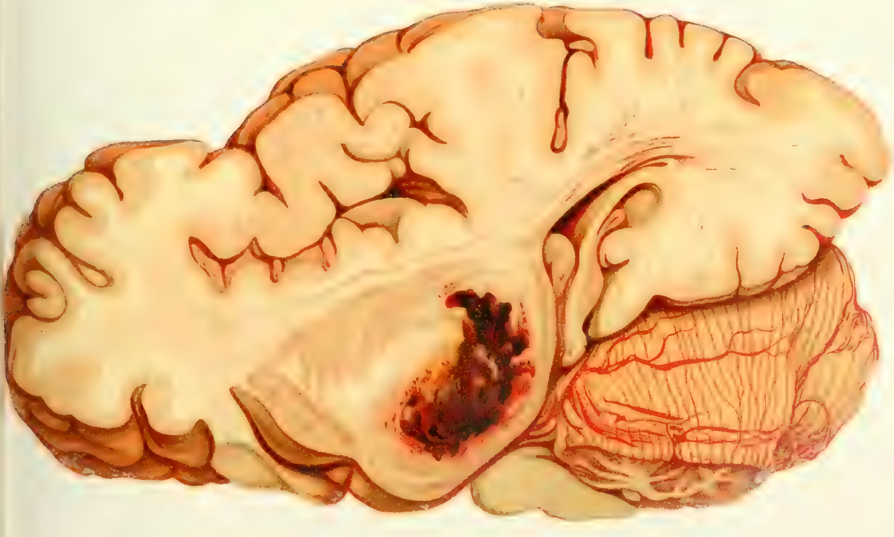


FIG. 2.

Intracranial Pathological Conditions. (After Bollinger)

Fig. I. Pachymeningitis Interna Hæmorrhagica. **Fig. 2. Apoplexy of the Right Hemisphere of the Brain.**

days. When consciousness is restored the paralysis present is more clearly defined and is found to consist usually of hemiplegia of motion, frequently associated with aphasia when situated on the right side of the body.

In a considerable proportion, perhaps the majority, of cases it is found, when the patient returns to consciousness, that sensation is also somewhat impaired on the paralyzed side. In addition it is not rare to find that hemianæsthesia of the special senses, associated with hemiopia, is also present. Gowers thinks that the latter symptom can be detected, in the majority of cases, during the first period after the attack. We have verified this observation in a number of instances. As a rule, the sensory disturbances disappear almost entirely within one or two weeks, though exceptionally they continue permanently, while the motor symptoms clear up in great part or entirely.

In the majority of cases improvement continues uninterruptedly after the restoration of consciousness until a certain definite degree of paralysis is left over. In a small proportion of cases, however, symptoms of cerebral irritation, probably owing to the development of encephalitis around the clot, make their appearance at the end of a week or ten days, sometimes as early as two or three days, after the occurrence of the hemorrhage. The patient then complains of severe headache, the temperature again rises, irritability, and even delirium may supervene. These symptoms may increase in severity and a fatal termination ensues, or, after lasting for a week or more, they may gradually disappear, leaving the patient in about the same condition as before the relapse. In some cases, rigidity or contractures develop during this condition, and subside with the other symptoms.

Acute decubitus (bedsore) may also develop during the early period of the attack. If this occurs, it will be found usually, from the second to the fourth day, that an erythematous patch appears upon the middle of the gluteal region of the paralyzed side, followed rapidly (usually the next day) by the formation of bullæ, and then by rapid sloughing of the parts. According to Diprat, the acute bedsore is sometimes observed upon the healthy side. Charcot states that death almost always occurs in such cases.

Vaso-motor symptoms may also be noticed from the very onset of the attack. The paralyzed side is then warmer to the feel than the non-affected side, and is covered with more profuse perspiration; sometimes the radial pulse is fuller on the hemiplegic side; slight œdema of the skin on this side is also often noticed. These symptoms disappear in proportion as the coma subsides, and, at a later period, may give place to vaso-motor symptoms of a different character, which will be mentioned later.

After the immediate effects of the hemorrhage have passed off, the patient may live for years without a recurrence. Subsequent attacks usually occur, however, unless the patient dies from an intercurrent disease.

The hemiplegia left over after an ordinary attack of cerebral hemorrhage presents the following characteristics:

The paralysis is not so well marked, as a rule, in the face as in the limbs. There is less expression and power of motion in the lower half of the paralyzed side of the face than on the opposite side, the naso-labial fold is partly or entirely effaced, and the angle of the mouth droops and sometimes is drawn closer to the median line. The frontalis and orbicularis palpebrarum usually act as well as those on the non-paralyzed side, though careful observation often shows that they do not contract quite as vigorously as normally. This is particularly noticeable if the patient be directed to close only the eye of the paralyzed side. The paralysis of the lower half of the face becomes more noticeable during voluntary movements, while in laughing both sides of the face may contract to an equal degree. Some difficulty in mastication may arise from the accumulation of food between the teeth and cheek of the affected side; more rarely there is slight disturbance of deglutition. The tongue, when protruded, may deviate to the side of the paralysis on account of the unopposed action of the genioglossus muscle on the healthy side. It must be remembered, however, that this deflection of the tongue may be more apparent at times than real, and that it may be owing to the closer approximation of the angle of the mouth on the paralyzed side to the median line. If the hemiplegia has occurred in early childhood it is commonly found after the lapse of a few years (the interval being shorter the earlier the age at which the hemorrhage occurred) that the bones of the skull and face on the paralyzed side are slightly smaller than those on the opposite side. The muscles are also atrophied to a slight extent.

Apart from aphasia, the discussion of which will be found in Vol. I., speech is usually not affected very much, though sometimes there is considerable thickness and slowness of speech from the diminished mobility of the tongue and lips, or perhaps from the impairment of mental power.

The upper limb is usually paralyzed to a greater extent than the lower limb, *i.e.*, the latter recovers much more rapidly and thoroughly than the former. The upper limb, as a rule, is partially flexed in all the joints, and the arm drawn alongside the chest. The power of executing coarse movements returns first, the delicate manipulations of the fingers being restored last. The tendon reflexes at the bend of the elbow and the wrist are increased.

In walking the lower limb drags along the ground, and there is an evident effort in propelling it along. It is swung more at the hip, and the pelvis is raised higher upon the paralyzed than upon the non-affected side in order to allow the drooping toes to clear the ground.

As an almost invariable rule in adults the paralyzed limbs do not undergo any noteworthy atrophy, although the paralysis may have lasted for years; the subcutaneous adipose tissue may disappear to a considerable extent. In rare cases, however, rapid atrophy takes place, sometimes even within a few months, and is more marked in the upper limb. It is supposed that this peculiar feature is owing to the implication of the anterior gray horns as a secondary result of the descending degeneration of the lateral columns. In one case under our observation the diagnosis of this secondary change in the cord was verified by the post-mortem examination.

In hemiplegia of early childhood marked atrophy of all the tissues of the paralyzed limbs always takes place, or, at least, their growth does not correspond with that of the healthy side. Sometimes this atrophy is so marked as to look, at the first glance, like that resulting from acute infantile paralysis.

The paralyzed limbs are usually cool to the feel, and the skin may present a dusky, mottled appearance from impaired circulation; not infrequently the radial pulse is smaller than on the other side.

In addition to these vaso-motor disturbances, trophic changes may also occur, and are more marked in the upper limb. The integument sometimes seems to be thinned and atrophic, in other cases it appears thicker than normal. The nails may become discolored, lose their gloss, and become rough from excessive development of longitudinal striations. The joints, particularly the shoulder, hip, and fingers, not infrequently become affected. The joint affection is very rarely acute in its origin. When this does occur, phenomena not unlike articular rheumatism are developed. This form usually begins in from two to four weeks after the apoplectic attack. Much more frequently, however, chronic, slowly progressing changes arise. The articular ends of the bones then appear to enlarge, and at the same time a certain amount of atrophy appears in the muscles surrounding the joint. No exudation can be detected, but the joint is very tender on pressure, and may be so painful on movement that the mobility is interfered with out of all proportion to the actual loss of muscular power. This condition is extremely obstinate, and frequently resists all forms of treatment.

Late rigidity, or contracture, is a very frequent sequel of hemiplegia. The upper limb is involved to a much greater extent than the lower limb. As a general rule the fingers are strongly flexed, sometimes bent forcibly into the palm of the hand; the wrist is flexed upon the forearm, and the latter is pronated and at the same time slightly flexed on the arm. Contracture of the pectoralis major muscle draws the arm against the chest. In the lower limb the contracture is confined chiefly to the muscles of the calf, which draw up the heel.

It is very often found, even in advanced cases, that the contracture disappears in great part when the patients awake in the morning. Then the fingers, which could not be extended previously without a very great effort on the part of the physician, are relaxed spontaneously, and the patient may even be able to execute voluntary movements. In a little while, however, the *status quo ante* is restored. This condition is always attended by a marked increase of all the tendon reflexes, and sometimes by increased mechanical excitability of the paralyzed muscles. It is generally believed that this form of contracture is due to descending degeneration of the lateral columns, but this view is not well founded. We have seen one case in which the contracture was absent, although well-marked descending degeneration was found at the autopsy. Were this theory true, the symptom in question should be present in all cases of hemorrhage or other lesion affecting the pyramidal tracts, but in reality it is not infrequently absent under such conditions.

The phenomenon known as "associated movements" is also observed quite often in hemiplegia, particularly when it occurs in childhood. As a rule, strong voluntary effort on the part of the non-paralyzed limbs is associated with an involuntary movement of the paralyzed parts. Much more rarely a vigorous attempt to move the paralyzed muscles is attended with an involuntary movement of the healthy side.

Post-hemiplegic chorea is another peculiar phenomenon, allied perhaps to the associated movements just referred to. It occurs with greatly preponderating frequency in the hemiplegia of childhood, but is observed not very rarely in adults. The period of its development varies greatly, but it never occurs until a very considerable amount of improvement has taken place. This symptom is also found to be much more pronounced in the upper than in the lower limb.

The movements are manifold in character. Sometimes they can be distinguished in no respect from ordinary chorea; and, as in the latter disease, in some cases the movements are increased on effort, in others they are diminished.

More rarely tremor is produced like that seen in paralysis agitans, or the movements may be coarser. Some cases have been observed in which the movements were of an ataxiform character, and it is even claimed that true ataxic disturbances may be produced. There is very little doubt that athetosis (slow, constant alternation of flexion and extension of the fingers, with corresponding movements, perhaps, in the upper portions of the arm, more rarely in the lower limb, particularly the toes) is merely a variety of post-hemiplegic chorea, though it may also occur independently of cerebral hemorrhage.

In children, in whom post-hemiplegic chorea is of very frequent occurrence, this symptom often becomes complicated with epileptiform convulsions, affecting at the onset only the paralyzed side, but later spreading usually to the other side.

DIAGNOSIS.—The recognition of cerebral hemorrhage is often attended with great difficulty, and indeed may be impossible. The disease is most frequently mistaken for cerebral embolism, since the symptoms of both affections may be identical. In such cases a provisional diagnosis can be made only from attendant circumstances. Embolism is usually associated with cardiac valvular disease, thrombosis of the heart, or aneurism of the arch of the aorta. As a matter of course, however, the existence of these lesions does not preclude the occurrence of cerebral hemorrhage. If the coma occurs with great suddenness, it is due more probably to embolism than to hemorrhage, and this is also true if the patient recovers, within a week, a considerable amount of power in the paralyzed side. Again, embolism is comparatively more frequent before the age of forty, though, as we have seen above, hemorrhage may also occur at any age, even in infancy and childhood. The determination of the co-existence of chronic interstitial nephritis favors the diagnosis of hemorrhage, on account of the vascular lesions so often present in the former disease. On the other hand, it must be remembered that the mere presence of albumin in the urine during an apoplectic attack possesses no significance whatever.

Cerebral hemorrhage must also be distinguished from cerebral thrombosis. In the latter affection, the comatose condition, if it develops at all, is usually much slower in its onset, though it must also be remembered that exceptionally the symptoms of thrombosis occur with great suddenness. The disease is peculiarly an affection of old age, and the radial, temporal, and other superficial arteries are generally found to be very atheromatous. When the thrombosis is the result of a syphilitic affection of the vessels, it is almost always preceded by another train of symptoms, a discussion of which will be found under the head of syphilitic lesions of the cerebral vessels.

Hemorrhage into the pons may also be mistaken for opium poisoning, if it is attended, as is usually the case, with strongly contracted pupils. In the former affection, however, the pulse and respiration are not so notably retarded as in the latter, and the coma is more profound. Epileptiform convulsions, also, are not an infrequent accompaniment of pons hemorrhage, and do not form a part of the history of opium poisoning. Of course the obscurity is cleared up if the patient recovers consciousness.

When the hemorrhage occurs during infancy or childhood, the disease must also be differentiated from tuberculous meningitis. This affection may also be attended with unconsciousness and sometimes distinct hemiplegia, even in cases in which the autopsy shows a tolerably uniform distribution of the lesion over both hemispheres of the brain. Meningitis, however, is attended with more marked prodromal symptoms than cerebral hemorrhage; the hemiplegia, if present, is not very profound, and is variable in degree at different times, as are also the other symptoms of the disease. In adults meningitis rarely simulates the history of cerebral hemorrhage.

But however careful we may be in the observation of the symptoms and of the attendant circumstances, very many cases will be encountered in which the diagnosis remains doubtful or is only cleared up by a post-mortem examination. Indeed, as was remarked in the paragraph on the pathological anatomy of the disease, even a post-mortem examination, if made long after the attack, may fail to decide the nature of the affection.

Even if a diagnosis of cerebral hemorrhage has been made, it is extremely difficult to localize the lesion accurately with any degree of certainty until the general pressure symptoms have cleared up, leaving only those which are due to the local lesion.

In the large majority of cases the most that can be done during the comatose stage is to determine the side on which the hemorrhage has occurred. The paralyzed side of the body is usually more relaxed than the non-paralyzed side, is often warmer, and the reflexes are entirely abolished; if conjugate deviation of the eyes and head is present, it is directed usually toward the side of the lesion. After the coma and the general pressure symptoms have subsided, localization of the lesion must be determined according to the principles laid down in this HANDBOOK under the headings, *Brain: Diagnosis of Local Lesions*, and *Brain: Functions of Cerebral Cortex.*

If the coma is very profound, and rigidity or convulsions make their appearance at the onset, together with serious respiratory and circulatory disturbances, the hemorrhage has probably occurred into the lateral ventricles (from surrounding parts). Hemorrhage into the pons is frequently attended by marked contraction of the pupils and profound coma, and when the paralysis can be determined, it is usually found to be alternate, *i.e.*, the face is paralyzed on one side, the limbs on the opposite side.

Prognosis.—This varies according to the size and situation of the hemorrhage. Other things being equal, life is more endangered the larger the hemorrhage. However, even hemorrhages of small size, if situated in the pons Varolii or medulla oblongata, are apt to prove rapidly fatal, and hemorrhages in the latter locality very rarely terminate in recovery. The fatal event is due to direct interference with the functions of respiration and circulation. Cheyne-Stokes respiration is an extremely unfavorable symptom, and is almost always a precursor of impending dissolution.

Large hemorrhages into the hemispheres, or those which rupture into the ventricles, also prove fatal, usually by direct or indirect pressure on the centres of the pons and medulla. The more sudden the development of coma, the smaller the chances of recovery. Acute decubitus, which occurs during the comatose stage, is almost invariably followed by death. The coexistence of Bright's disease is also a very unfavorable complication.

As regards the extent of recovery from the paralysis, very little can be foretold in the first period of the disease. In the large majority of cases the sensory disturbances disappear in great part and very rapidly.

Power of motion is usually restored much more quickly in the lower than in the upper limb. When the reverse obtains, it has been generally held that an unfavorable termination will ensue, but this opinion does not appear to be well substantiated.

The occurrence of late rigidity must be regarded as an unfavorable symptom, insomuch as it interferes, in the first place, directly with the power of motion, and, in the second place, improvement in the latter usually ceases with the appearance of the former. This also holds good of post-hemiplegic chorea.

Symptoms of mental deterioration are usually permanent, and indeed, in many cases, are steadily progressive. As a rule, however, it is only after repeated attacks that a condition of mental impairment, amounting even to imbecility, develops. In very exceptional instances, epilepsy follows cerebral hemorrhage.

Treatment.—Prophylactic treatment is practically nil. If the prodromal symptoms are prolonged, the patient should be kept as quiet as possible, mentally and physically, and care taken that the bowels be kept thoroughly open. When the onset of a hemorrhage has been suspected, I have been in the habit of putting my patient to bed for a week, giving bromide of potassium in fifteen to thirty grain doses, t.i.d., and a mild laxative or enema daily.

If the hemorrhage has taken place or is occurring at the time the physician is called, very little, if anything, can be done to check it. Drugs given internally for this purpose do more harm than good. The most that should be done is to keep the head slightly elevated, and if the carotids and temporals are pulsating strongly, apply cold applications to the head or leeches to the forehead. If the pulse continues strong during the comatose stage, nothing more need be done. When evidences of heart failure arise ammonia and stimulants are indicated.

When the stationary stage of paralysis has developed, treatment is useless until after the lapse of a considerable period. The natural tendency of the paralysis is toward improvement (though complete recovery hardly ever occurs), and until this tendency becomes manifest, we may rest satisfied either that motor fibres are cut across or that pressure is still exerted at the site of the lesion, thus interfering with nervous conduction.

Almost the only means at our command to hasten recovery is the use of electricity. This may be employed in two ways, either to the brain itself or directly to the paralyzed parts

The former method has been very little used hitherto, and, indeed, it is not probable that much good can be expected from it. The galvanic current alone is employed for this purpose. The positive pole is usually applied to the side on which the hemorrhage took place, the negative pole on the opposite side of the head. The current should be mild, and must never be strong enough to produce vertigo; the sittings should not exceed from two to five minutes in duration.

The ordinary method (and the one which promises by far the best results) of employing electricity in hemiplegia is the direct application of the faradic current to the paralyzed muscles. It has generally been held that this measure should not be employed until at least two or three months have elapsed since the occurrence of the hemorrhage, for fear of causing a recurrence of the disease. There is very little reason, however, to doubt that this fear is entirely unfounded, and that it is perfectly safe to begin the treatment within two or three weeks after the stationary period has begun.

The strength of current employed should be merely sufficient to produce distinct contraction of the paralyzed muscles; the sittings may be held every other day, and their duration may vary from five to fifteen minutes.

In a few cases an astonishing degree of improvement occurs after the first two or three applications, after which very little, if any, progress is made. As a rule, however, improvement, if it occur at all, is very gradual, and the treatment must be continued patiently for months.

When contractures of the paralyzed limbs have developed, another method should be employed. The one usually adopted is the application of the stabile galvanic current through the nerves and muscles (nervo-muscular current) of the flexor aspect of the limbs (the parts in which the contracture is usually situated) and the faradic current to the antagonists. Warm baths and massage are also useful for this purpose.

In some cases painful swelling of the joints is extremely annoying to the patient, and this complication is very intractable to treatment. It is best combated by the use of a strong stabile galvanic current passed directly through the joint, with the addition of repeated small blisters over the site of pain.

Iodide of potassium, in doses of from five to ten grains t.i.d., is usually administered as a matter of routine, but it is more than doubtful whether this drug exerts any beneficial effect.

In our hands ergot has never given good results, no matter in what stage of the disease it has been employed. Careful attention should always be paid to the condition of the bowels, particularly as the patients are apt to be constipated for a long time after the attack.

Leopold Putzel.

BRAIN: CEREBRO-SPINAL FLUID.—(Synonyms: *cœliolymph*; Ger., *Cerebrospinalflüssigkeit*; Fr., *liquide céphalo rachidien*; Lat., *liquor cerebrospinalis.*)

Anatomy.—The cerebro-spinal fluid is found in the encephalic and myelic ventricles, and in the subarachnoid and subdural spaces. It varies in amount from 60 to 200 c.c., increasing somewhat with age. It is not lymph and is sufficiently characteristic in its reactions to be distinguished from other serous fluids. The subarachnoid space is the interval between the arachnoid and the pia, very narrow on the upper and lateral aspects of the encephalon, crossed by numerous bands of arachnoid tissue, but enlarged in certain regions at the base, above the corpus callosum and over the optic lobes, called the cisternæ subarachnoidales.

These are in communication with one another and have as tributaries the clefts along the great fissures (flumina), which themselves have as tributaries the spaces along the secondary and tertiary fissures (rivi and rivuli of Duret). There are prolongations of this space around the optic, olfactory, and auditory nerves, and a connection with the lymph spaces around the other cranial and spinal nerves. Communications with the lymphatic vessels of the nasal mucous membrane and deep vessels and nodes of the neck also exist. These connections have been demonstrated by the injection of the subarachnoid space with colored fluids which have filled the lymph vessels of the nasal mucous membrane, traversed the lymph spaces of the nerves, and penetrated the deep cervical vessels and nodes. The colored fluid has also been observed to pass into the dural sinuses through the arachnoidal villi, probably indirectly by filtration. Flatau,[1] by the injection of colored fluids, was able to make them escape from the nose. Naunyn and Schreiber, quoted by Flatau, have demonstrated the same thing, using salt solution, the flow from the nose being accompanied by protrusion of the eyeball and chemosis.

According to Binswanger and Berger[2] the subarachnoid space also receives the lymph from the adventitial lymph spaces of the cerebral cortex. They observed that in cases of intraventricular hemorrhage in the human subject, blood would make its way into the subarachnoid space and thence into the intra-adventitial spaces of the cortex. Injection of a carmine mixture into the subarachnoid of a dog likewise filled the cortical intra-adventitial spaces.

These observations confirm those of Key and Retzius.

Subdural injection of colored material has demonstrated the following connections with the subdural space (Schwalbe[3]):

1. The deep lymph vessels and nodes of the neck.
2. The subdural spaces of the nerve roots and lymph paths of peripheral nerves (Key and Retzius).
3. The lymph paths of the dura through fine clefts (Michel).
4. The dural sinuses through the arachnoidal villi.

The ventricles communicate with the subarachnoid space by the foramen of Magendie (metapore) and the aperturæ laterales (foramina of Luschka). The connection described by Merkel and Mierzejewsky in the descending horn of the lateral ventricle is probably an artefact. The existence of the metapore and the aperturæ laterales has recently been confirmed by Blake.[4]

There is no direct connection between the subarachnoid and subdural spaces, but the lymphatics of the nasal mucous membrane, the lymph spaces of the nerves, and the cranial sinuses through the arachnoidal villi can be injected from both cavities.

The histology of the choroid plexuses of the lateral ventricles has recently been investigated by Findlay,[5] who finds that there are for the most part several layers of cells on the villi and that the surface cells may contain globules which are extruded, leaving the empty cell membrane. These globules may be found in the ventricular fluid. They darken with osmic acid and are probably fatty in nature.

Blood-vessels are very numerous in the choroid plexuses, and nerves too have been demonstrated in the plexuses of the lateral and fourth ventricles (Benedikt), so that structurally they are secretory in character.

The morphological elements are very scarce in the normal fluid and consist of a few leucocytes, endothelial cells, and occasional globules of a fatty nature derived from the cells of the choroid plexuses.

The experiments of Key and Retzius,[6] confirmed by Kollman, seem to show that one of the outflow paths for the subarachnoid and subdural spaces is by the way of the arachnoidal villi into the cranial sinuses. More recently it has been demonstrated that normal saline solution tinged with methylene blue and injected into the subarachnoid space can be traced passing into the sinuses and veins, and in a few minutes the blue is found in the stomach and bladder; but it is only after one hour of steady injection that the deep cervical nodes begin to be tinged. The rapid absorption then takes place rather by the blood-vessels than by the lymphatics.

The amount of cerebro-spinal fluid increases with age and with brain atrophy, and decreases in those diseases in which the volume of the brain is augmented; it also varies with the amount of blood in the intracranial vessels.

Physiology.—The cerebro-spinal fluid forms a water bed on which rests the base of the middle and posterior parts of the encephalon. It performs an important function in protecting the brain from injury and the circle of Willis from compression. It also helps to dissipate the force of a blow, so that less injury is done at the point of its reception. This may result in a disruption of brain substance in a region far removed from the place of injury. For example, a blow received on the front of the head in a direction downward and backward may cause hemorrhages in the region of the medulla and fourth ventricle, as a result of the ventricular fluid trying to pass through the narrow aqueduct of Sylvius (Park[7]).

Sudden tapping of this water bed may occasionally result in injury to the brain from the sudden changed relations of the encephalon to its rigid bony case; also where the ventricles have been distended, the sudden withdrawal of fluid may leave parts unsupported, resulting in injury to the brain tissue.

According to A. and E. Cavazzani[8] secretion and absorption of the cerebro-spinal fluid proceed slowly. To test the rate of secretion, ferrocyanide of potassium was injected into the peritoneal cavity of a curarized dog. The salt did not appear in the cerebro-spinal fluid until after an hour had elapsed.

To test the rapidity of absorption the posterior occipito-atlantal ligaments were opened and 4 c.c. of a fifty-per cent. solution of iodide of potassium was injected into the arachnoid space, and the same solution was also injected into the encephalic arachnoid cavity. The salt was found in the urine in a minimal time of twenty minutes, and a maximal time of two hours. The great difference of time in absorption was accounted for by the variations in pressure of the cerebro-spinal fluid and the blood.

Thomson's[9] observations, in several cases, of the spontaneous flow of cerebro-spinal fluid from the nose show that the secretion may be quite rapid, the flow averaging 500 c.c. in twenty-four hours. Hill[10] has shown that the rate of secretion depends on the cerebral capillary pressure and that this can be easily raised by (*a*) compression of the abdomen, (*b*) by assumption of the horizontal position, and sometimes (*c*) by forced expiration with the glottis closed, *i.e.*, in straining. When, however, the amount of fluid is increased, its chemical characters change, the proportion of solids decreasing.

A. Spina[11] has shown that increased arterial pressure due to intravenous injections of suprarenal extract in curarized dogs causes a clear fluid to exude from the cerebral surface drop by drop. This fluid he considers a transudate. It is probable that the cerebro-spinal fluid retains its peculiar characters under normal conditions of pressure only, and after it is withdrawn, its place is taken largely by extraventricular serous transudate.

There are three sources for cerebro-spinal fluid, and its character is dependent upon the proportions furnished by the different sources. The first and most important origin is as a secretion into the ventricle from the choroid plexuses; second in importance, as a transudate into the subarachnoid and subdural cavities; and third, from the intra-adventitial lymph spaces of the cortex. The relative amount of the intra- and extraventricular fluid varies from time to time, depending on the intravascular and intracranial pressures, a preponderance of the intravascular pressure resulting especially in an increase of the extraventricular fluid. The tension of the cerebro-spinal fluid is from 5 to 7.3 mm. of mercury, and about equals that of the blood in the capillaries, varying however in different individuals.

The osmotic tension of the cerebro-spinal fluid is greater than that of serum (Zanier).

The cerebrum increases in volume with the cardiac systole and expiration, and decreases with the cardiac diastole and inspiration. Accompanying the cerebral movements is an ebb and flow of the cerebro-spinal fluid from the cranial into the spinal spaces where extra room can be had by the expansion of the ligaments and the spaces around the spinal nerves. More room may also be had for the brain by the expression of blood from the encephalic veins and sinuses. There is, however, very little motion of translation of the fluid accompanying the cerebral movements (Elder). Whenever the intracranial pressure exceeds the cerebral venous pressure, the fluid rapidly leaks away, and hence may be left out of account in the pathology of compression (Hill).

The effect of intravenous injection of cerebro-spinal fluid has been investigated by Mott and Halliburton.[12] They found that if the fluid is taken from animals, or from cases of meningocele or chronic hydrocephalus in man, and injected into the veins of animals, no effect is produced. If, on the contrary, the fluid is obtained from cases of brain atrophy, especially from cases of general paralysis of the insane, then a marked lowering of arterial tension is noticed, partly cardiac in origin but principally due to the local action of the poison on the neuromuscular apparatus of the peripheral vessels, especially in the splanchnic area. This is believed to be due to a toxic substance called cholin derived from the disintegration of the lecithin in the brain.

CHEMISTRY.—There are several ways in which the cerebro-spinal fluid may be obtained for examination. (1) From cases of chronic hydrocephalus, either by puncture during life or after death. In acute hydrocephalus the fluid is not normal, but is an exudate. (2) In cases of meningocele and spina bifida the fluid is normal, but only the first tapping can be so considered, as its character changes in the later tappings. (3) By lumbar puncture. (4) The fluid may be collected in cases of fracture at the base of the cranium, as it drops from the nose or ear. (5) In cases of spontaneous flowing from the nose and ear. (6) In animals, by establishing a permanent fistula, as suggested and employed by Cavazzani,[13] to study qualitative and quantitative variations.

The cerebro-spinal fluid is a clear watery fluid, slightly saline to the taste, of low specific gravity, about 1.007. The density increases in proportion to the greater amount of transuded to secreted fluid, and it is also higher in the morning than in the evening (Thomson). Its reaction is slightly alkaline or neutral, being more alkaline in the morning than at night. The reaction has been investigated in diseased conditions by Turner,[14] who found in thirty-seven cases of insanity that it was acid to phenolphthalein, alkaline to methyl orange; and in thirty cases tested with litmus there was an amphoteric reaction in twenty-nine, the red paper finally turning blue, with an acid reaction in one case only. These same reactions were found whether the test was made immediately after death or several hours later.

The chemical composition of the cerebro-spinal fluid is shown in the following analysis, made by Halliburton,[15] of fluid removed from cases of spina bifida.

	Case 1. Female aged nineteen years, in parts per 1,000.	Case 2. Child aged eleven days, first tapping, in parts per 1,000.	Case 3. Child aged thirteen weeks, fourth tapping, in parts per 1,000.
Water	989.75	989.877	991.658
Solids	10.25	10.123	8.342
Proteids	.842	1.602	.199
Extractives	9.626	.631	3.028
Salts		7.890	5.115

A comparison of the relative proportion of solids in several of the watery fluids of the body is shown in the subjoined table (Beaunis):

	Water.	Solids.
Lymph	95.8	4.2
Serum	95.9	4.1
Aqueous humor	98.6	1.4
Tears	98.2	1.8
Cerebro-spinal fluid	98.8	1.2

In normal cerebro-spinal fluid, proteids are small in amount, and somewhat variable in quantity and kind. Fibrinogen is absent, as no fibrin is formed by the addition of fibrin ferment. Serum albumin is absent, as all of the proteid is precipitated by saturation with magnesium sulphate. There are probably present, however, serum globulin, generally proto-albumose, sometimes hetero-albumose, and occasionally peptones. An increase in proteids is likely to occur in tappings subsequent to the first, but never equalling that found in inflammatory hydrocephalus.

The following analysis, in the case of a boy six months old with chronic hydrocephalus, illustrates this (Halliburton[15]):

	Specific gravity.	PROTEID.		Reducing substance.
		Percentages of total proteids.	Kinds of proteid present.	
First tapping.	1.006	0.045	Globulin .... Proto-albumose. Hetero-albumose.	Traces.
Second "	1.010	0.069	Same as first tapping. Serum globulin.	Fairly abundant.
Third "	1.010	0.272	Serum albumin. Traces of albumoses.	More abundant.

One of the most interesting features of the chemistry of the cerebro-spinal fluid is the presence of a substance which, like sugar, reduces copper salts. It has been considered grape sugar by many observers (Bernard, Cavazzani, Nawratzki,[16] and Panzer[17]).

Nawratzki studied this fluid in the calf, horse, and man. In the calf, working with two litres of fluid, he found a substance which reduces copper and bismuth oxide in alkaline solution, and gives the phenylhydrazin reaction. He obtained crystals having the form and melting point of phenylglucosazon, 205°–206° C. He failed to find pyrocatechin, peptone, or albumose, and considers the proteid a globulin. He claims that the reducing substance disappears shortly after death, and cites two cases in which the fluid drawn by lumbar puncture during life showed strong reducing action, but in the same individuals after death this action was lost. Halliburton always finds the reducing substance, but claims it is not grape sugar, for the following reasons: (1) It does not reduce bismuth salts; (2) it does not ferment with yeast; (3) it does not rotate the polarization plane; (4) it does not yield a crystalline compound with phenylhydrazin, as does sugar.

This reducing body can be obtained as follows:

"Acidified alcohol is added in excess to the fluid, to precipitate proteids; this is filtered off. The filtrate is evaporated to dryness over a water bath; the dry residue is again taken up with alcohol, filtered, and again evaporated to dryness" (Halliburton).

The crystalline deposit is the reducing substance and belongs to the aromatic group of organic compounds. It is soluble in ether, alcohol, and water, gives a green coloration with ferric chloride, brown with caustic alkalies, has a pungent taste and an acid reaction, and its crystals are needle-like and similar to those of pyrocatechin. Halliburton considers the reducing substance a normal constituent of the cerebro-spinal fluid, contrary to Hoppe-Seyler, who finds it subsequent to the first tapping only. It certainly increases in amount after the first tapping (see analysis). Whether it exists in a combined or an uncombined state is not known.

Some observers have noted an unusual preponderance of potassium salts, but later ones have found the proportion no greater than that of the blood, lymph, or transudates generally.

Briefly stated, the chief chemical characteristics of the cerebro-spinal fluid are the following:

1. It is a clear watery fluid, faintly alkaline, of low specific gravity, about 1.007.
2. It contains no fibrin and gives no precipitate (mucin) on adding acetic acid.
3. On boiling not more than a trace of turbidity (serum globulin) is observed.
4. It reduces Fehling's solution.
5. A reducing substance, obtained by evaporating to dryness an alcoholic extract of the fluid, is found in needle-like crystals having a pungent taste and an acid reaction, and resembling pyrocatechin. This reducing substance does not ferment with yeast, nor give the phenylhydrazin reaction, nor turn the polarization plane.
6. It contains a small proportion of proteids and generally no albumin.

Pathological and Clinical Considerations.—Since Quincke called attention to the value of puncture of the vertebral canal as a diagnostic and therapeutic measure, and to the ease with which it could be performed, resort to it has frequently been had.

The method of procedure is as follows:

The patient is preferably placed in the recumbent posture on the left side, with the body strongly flexed in the lumbar region. The puncture is made with a long aspirating needle between the second and third or the third and fourth lumbar vertebræ, a few millimetres outside the median line. In a child of about two years, the puncture should be opposite the mid-point between the lumbar spines, and at a depth of about 2 cm. the subarachnoid chamber will be reached. In the adult the puncture should be made at a point opposite the middle third of the lower border of the spine above, on account of the downward inclination of the spines, and the needle should slope toward the median line. If the puncture be made in the median line, it should be at the mid-point between the spines; and in children the needle should penetrate in a nearly horizontal direction, while in the adult it should slope upward parallel to the spines. Sahli[18] recommends that the puncture be made between the fifth lumbar and the base of the sacrum, especially if the morphological elements are to be sought for. Anæsthesia is, as a rule, unnecessary.

Where there are symptoms of intracranial pressure and only small amounts of fluid can be obtained by puncture, the cause will probably be an interruption of the connection between the encephalic and spinal spaces, due to exudate or tumor, especially of the cerebellum. It is possible, however, that the lack of fluid might be due to the closure of the aqueduct of Sylvius or the metapore. Small quantities of fluid exclude tuberculous meningitis, acute hydrocephalus, and tetanus.

The cerebro-spinal pressure can be judged by the strength of flow from the cannula, a strong spurt indicating an increased pressure, slow-coming drops a decreased pressure. It can be more accurately measured by attaching the cannula to a mercury, or, better, to a water manometer, the normal pressure being from 5 to 7.3 mm. mercury. When the pressure is much raised (15 to 60 mm. of mercury) meningitis or brain tumor is indicated. The specific gravity is somewhat variable, but an increased density points to meningitis, although this affection may exist with normal specific gravity.

Proteids may be found increased in tuberculous meningitis, decreased in brain tumors and serous meningitis. The variation in different cases of the same kind is so great that the proportion of proteids loses considerably in diagnostic significance. Lichtheim and Quincke claim to find sugar in most cases of brain tumor. This does not agree with the observations of Fürbringer, who found sugar only in cases of diabetes associated with tuberculosis.

Microscopic Examination.—A turbid appearance is due to leucocytes and indicates inflammation, but in tuberculous meningitis the fluid is clear.

In tuberculous meningitis, tumor, abscess, and chronic hydrocephalus only a few leucocytes and endothelial cells are to be found, while in acute meningitis the leucocytes are more plentiful, and in the purulent form they are very numerous. It is important, before advising operation in cases of abscess of brain and sinus thrombosis, to exclude purulent meningitis. This is often readily done by a microscopic examination of the puncture fluid.

Pure blood in the subarachnoid space indicates either extensive brain laceration or intraventricular hemorrhages. In subdural hemorrhages, a small amount of blood may be found; but in epidural hæmatoma, and in hemorrhagic pachymeningitis only very small quantities of blood are found. In severe traumatic cases the presence of nearly pure blood would indicate serious brain injury and contraindicate operation, and vice versa; the absence of blood might indicate the advisability of an operation. In non-inflammatory diseases of the brain, as tumors or abscess, no clotting occurs, except a slight one in tuberculous meningitis.

In cases in which tuberculous meningitis is suspected, some of the puncture fluid should be centrifugalized and examined for tubercle bacilli. Fürbringer has found the bacilli in thirty out of thirty-seven cases. Other organisms that have been found are the diplococcus intracellularis (Weichselbaum) in cases of epidemic cerebro-spinal meningitis, and the streptococcus and the diplococcus pneumoniæ in purulent meningitis secondary to otitis media. The staphylococcus pyogenes aureus and albus are also sometimes found.

St. Clair Thomson has collected from the literature nine cases of undoubted spontaneous flow of the cerebro-spinal fluid from the nose, and twelve probable cases. This condition he has named cerebro-spinal rhinorrhœa. It affects the sexes about equally, and is a disease of adult middle life, frequently presenting cerebral and eye symptoms. The flow is usually from the left side of the nose and is generally continuous day and night, but long or short periods of intermission may occur.

The method of escape of the fluid was found in one case to be through an aperture in the cribriform plate of the ethmoid. A possible explanation is that the lymph vessels of the nasal mucous membrane, which are in communication with the subarachnoid cavity, may furnish the exit. No efficient method of treatment has been found. One case of spontaneous flow from the ear is recorded in which the membrana tympani was intact and no evidence of injury or disease was present.

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BRAIN, CIRCULATION OF.—All the larger intracranial vessels and most of their easily visible branches lie in the enveloping membranes—dura, pia, and their processes. Over the convexity only minute branches enter or leave the brain proper. The largest arterial twigs directly entering the cerebrum are those of the (basal) pre- and post-perforated spaces. The largest

EXPLANATION OF PLATE XVI.

EXPLANATION OF PLATE XVI.

Fig. 1.—The arterial areas of the convexity

Fig. 2.—Those of the mesial surface. The area supplied by the precerebral is in brown, that by the medicerebral is in green, and that by the postcerebral is in blue. The main branches and their directions in each case are indicated by shades of the primary color.

The two figures on this plate were prepared especially for this work. They represent an average between the two sides of a brain examined by isolated injection of the individual arteries.

PLATE XVI.

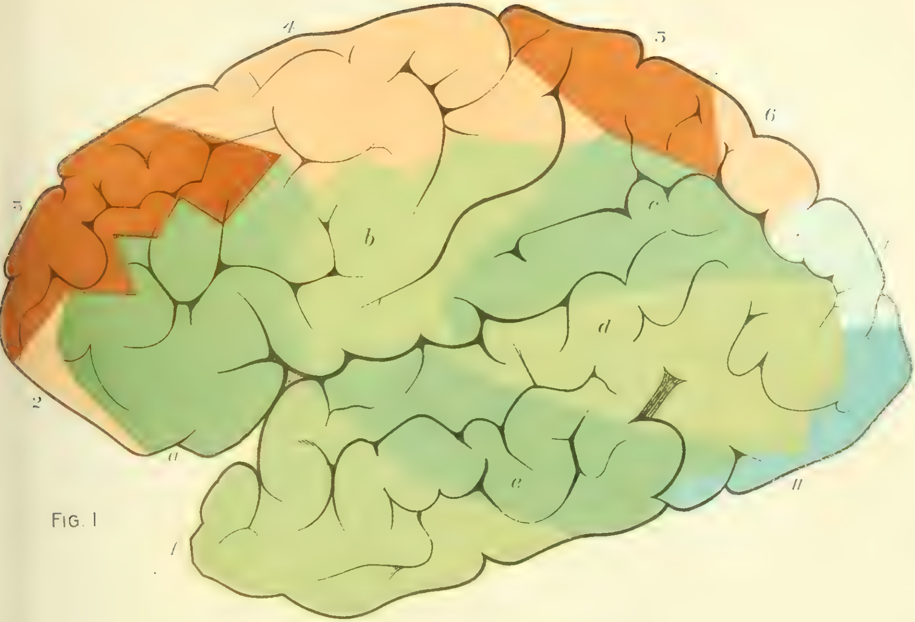

FIG. 1

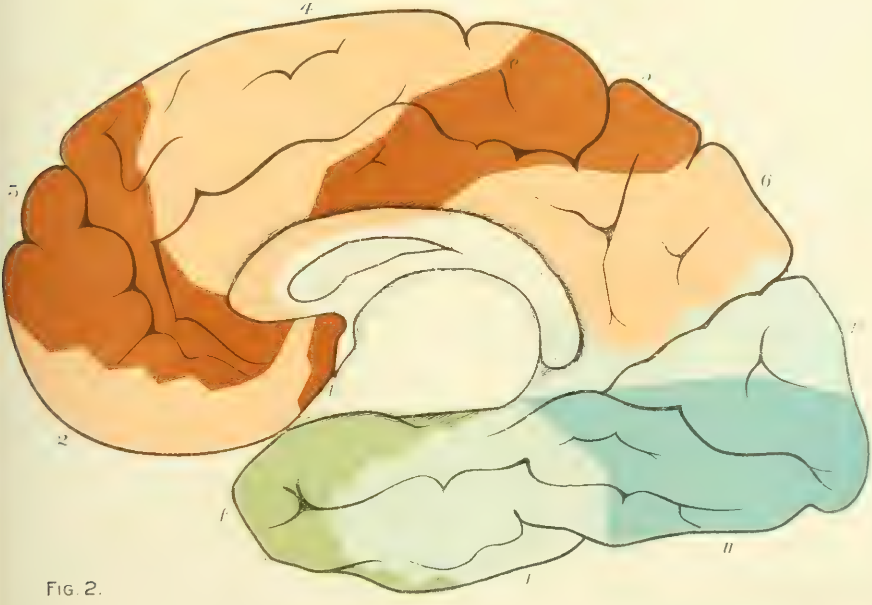

FIG. 2.

Arterial Distribution over Convexity (Fig. 1) and Mesial Surface (Fig 2): Precerebral in Brown: Medicerebral in Green: Post-Cere-

venous rootlets directly from the organ are the corresponding perforants and some in the cœles. Hence the vessels of the meninges have to be included in any account of the encephalic circulation; and the vascular distribution—especially the arterial—can be best mapped out on the surface. From studies published within the last thirty years our knowledge of this subject has been greatly developed. Our aim is to reclassify and harmonize the often puzzling independent and re-discoveries.

NOMENCLATURE.—In this article the simplified terms of Wilder (*vide* amended list in New York *Medical Journal*, November 25th, 1885) will be employed. These are extended also—with his approval—to the veins, sinuses, and so-called meningeal vessels. As these last lie wholly in one of the membranes, the dura, the general term *meningeal* does not accurately define them; for this the unequivocal *dural* is substituted.

Intrinsic Arteries of the Brain.

Common Latin names.	Proposed names.	English paronyms.	Abbreviations.
Vertebralis	Vertebralis	Vertebral	*vrtb.*
Basilaris (*az.*)	Basilaris	Basilar	*bslr.*
Cerebellaris superior	Precerebellaris	Precerebellar	*prcbl.*
Cerebellaris anterior	Medicerebellaris	Medicerebellar	*mcbl.*
Cerebellaris inferior	Postcerebellaris	Postcerebellar	*pcbl.*
Cerebralis anterior Corporis callosi	Precerebralis	Precerebral	*prcb.*
Cerebralis media Fossæ Sylvii	Medicerebralis	Medicerebral	*mcb.*
Profunda cerebri Cerebralis posterior	Postcerebralis	Postcerebral	*pcb.*
Communicans anterior (*az.*)	Precommunicans.	Precommunicant.	*prcm.*
Communicans posterior.	Postcommunicans	Postcommunicant	*pcm.*
Choroidea anterior	Prechoroidea	Prechoroid	*prchrd.*
Choroidea posterior	Postchoroidea	Postchoroid	*pchrd.*
Perforantes anteriores	Preperforantes	Preperforants	*prpf.*
Perforantes posteriores.	Postperforantes	Postperforants	*ppf.*
Termatica Cerebralis ant. media (*az.*).	Termatica	Termatic	*trmc.*

Dural Arteries.

Meningea	Duralis	Dural.
Meningea anterior	Preduralis	Predural.
Meningea media	Mediduralis	Medidural.
Meningea parva	Parviduralis	Parvidural.
Meningea posterior	Postduralis	Postdural.
Meningea inferior	Subduralis	Subdural.

Sinuses.

Longitudinalis superior (*az.*).	Longitudinalis	Longitudinal.
Longitudinalis inferior (*az.*).	Falcialis	Falcial.
Torcular Herophili Confluens sinuum (*az.*).	Torcular	Torcular.
Sphenoparietalis Alæ parvæ	Sphenoidalis	Sphenoidal.
Petrosus superior	Superpetrosus	Superpetrous.
Petrosus inferior	Subpetrosus	Subpetrous.
Petrosus anterior	Prepetrosus	Prepetrous.
Rectus (*az.*)	Tentorii	Tentorial.
Lacunæ laterales sinuum.	Lacunæ parasinuales.	Parasinual * spaces.

Intrinsic Veins of the Brain.

Cerebri superior	Supercerebralis	Supercerebral.
Cerebri anterior Callosi anterior externa	Precerebralis	Precerebral.
Cerebri media	Medicerebralis	Medicerebral.
Fossæ Sylvii	Sylvii	Sylvian.
Basilaris Rosenthali Cerebri inferior s. ascendens	Subcerebralis	Subcerebral.
Occipitalis lateralis Cerebralis lateralis et inferioris	Postcerebralis	Postcerebral.
Occipitalis interna Cerebri posterior inferior	Suboccipitalis	Suboccipital.
Callosi posterior externa.	Callosalis	Callosal.
Magna Galeni Cerebri interna communis (*az.*).	Galeni	Galen's.
Cerebri interna s. intima s. profunda Right and left vein of Galen	Velaris	Velar.
Corporis striati Lateralis ventriculi	Tænialis	Tenial.
Cornu anterioris	Precornualis	Precornual.
Septi lucidi Antr.-ventriculi	Paraseptalis	Paraseptal.
Cornu posterioris	Postcornualis	Postcornual.
Choroidea	Medicornualis	Medicornual.
Medullares superiores	Superalbales	Superalbals.
Rami corporis striati	Striatales	Striatal.
Rami thalami optici	Thalamici	Thalamic.
Ramus thalami optici profundus (Rosenthal) Pedunculi cerebri	Thalamocruralis	Thalamocrural.
Azygos conarii	Conarialis	Conarial.
Cerebelli sup. media	Supercerebellaris.	Supercerebellar.
Cerebelli sup. lateralis	Paracerebellaris	Paracerebellar.
Cerebelli inferior	Subcerebellaris	Subcerebellar.

Dural Veins.

Duræ matris cerebri Meningea	Duralis	Dural.
Meningea media	Mediduralis	Medidural.
Ophthalmomeningea	Ophthalmoduralis	Ophthalmodural.

ARTERIES.

The encranial arteries present two distinct systems of vessels:

I. The dural, commonly called meningeal.

II. The intrinsic, or those of the brain proper.

These latter do not anastomose with any other arteries. Rarely there are marked exceptions to this rule, and perhaps oftener slight inosculations about the sella turcica.

Heubner (1874), from injections in adults, says: "The territories of the medidural and of the cerebral arteries must be considered as absolutely independent of one another." Langer (1877), speaking of infantile and young subjects, states: (*a*) that one or two dural branches of the precerebral anastomose in the falx with terminal twigs of the dural artery; (*b*) also that pial branches of the precerebral may reach minute dural arteries accompanying the supercerebral veins as they spring over to the dura near the longitudinal sinus.

I. THE DURAL VESSELS ramify in the exterior of the dura. In a general way it is true that the pre-medi- and post-dural arteries are branches respectively of the internal and external carotid and vertebral arteries. These various branches interanastomose freely, so that dural infarction does not occur. They are distributed not simply to the dura, but also to the diploic cranial bones; small twigs may also pass to extracranial parts.

1. *The Branches from the External Carotid* supply the middle belt, and, in fact, nearly the whole of the dura. They are:

(1) The *Medidural*, the largest and most constant of all the dural arteries, arising from the internal maxillary and entering through the spinous foramen. Its branches pass up the divergent sulci meningei (for arteries and accompanying veins) of the lateral cranial wall, connecting at the top with those from the opposite side. Of its two main divisions, the larger anterior is often for a short distance arched over to a canal.

The furrows of the medidural artery on the entocranial wall deepen with years, and in old age the artery sinks quite into them. It has two primary branches, a larger cephalic and a caudal, the former again soon (at the sphenoidal angle of the parietal bone) separating into two secondary rami. The anterior ramus runs up behind the coronal suture, though a little more obliquely, being, according to Marchant, pretty constantly from 0 to 13 mm. (averaging 5 to 6 mm.) away at the foot of the suture, about 1 cm. at its middle, and 15 mm. at its dorsal part. The second ramus starts on the entotemporal surface 4 cm. behind the pterion, on an average. At its middle, on the entoparietal surface, it averages 54 mm. behind the coronal suture. Farther dorsad, the distance is very variable, 30 mm. more or less.

The primitive caudal branch leaves the temporal squama 58 mm. behind the pterion, then goes toward, and becomes parallel with, the lambdoidal suture.

The relations of these vessels to the subjacent cortex, important clinically, Duchaine sums up thus: (1) The cephalic branch runs up opposite the frontal lobe some centimetres before the central fissure, rather nearer the coronal suture. (2) The midramus starts almost opposite the fissure, then runs up some centimetres behind it. (3) The caudal branch is always a centimetre or more distant from the fissure, and is still farther separated above.

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* The form parasinual was kindly suggested and approved by Prof. B. I. Wheeler, the comparative philologist.

Besides many minute branches to the sinus walls, outgoing nerves, and orbit (*vide infra*), it may send to, or receive from, the deep temporal region minute rami perforating the interposed wall; in young subjects (Hyrtl) considerable branches may pass through the anterior fontanelle and the sagittal suture to the soft cranial coverings.

(2) The *Parvidural*, an inconstant accessory medidural, arising close to the latter, or even directly from it, and entering by the oval foramen. It goes to the Gasserian ganglion and adjacent dura.

(3) The *Mastoid* branch of the occipital (or external carotid, 15 in 120 times, Wyeth, 1878), entering by the mastoid foramen, within which it always sends a branch to the diploë. It is small, variable, and destined for the wall of the lateral sinus and adjacent dura. Here again a reverse course has been observed, where the postauricular arose from a dural artery by emerging through a foramen in the mastoid (Bankart).

(4) *Supradural* branch or *Ramus Parietalis*, also from the occipital, accompanying the emissary through the parietal foramen. It is usually insignificant, and often absent.

(5) The *Subdural* branches are very small and variable. They include twigs from the ascending pharyngeal, occipital, and stylomastoid arteries, enter by the pre- and post-lacerated, precondyloid, and stylomastoid foramina, and partly supply the dura of the posterior fossa and basilar sinuses.

2. *Branches from the Internal Carotid.*—(1) The cavernous carotid yields several small rami to the sinus wall, the pituitary body, Gasserian ganglion, and dura about the sella turcica. These are variously styled *receptacular* and *rayed arteries*, even predural in case of any prominent single branch. Their field of distribution and that of the parvidural are evidently complementary.

(2) The *Predural* usually refers to the one or more slight branches of the ethmoidal arteries, supplying the adjacent dura of the precranial fossa.

3. *Branch from the Vertebral.*—The *Postdural* artery arises opposite or just below the occipital foramen, passes with the vertebral into the cranial cavity, and supplies the dura of the postcranial fossa, especially the posterior portions, as the cerebellar falx, etc.

The only anastomoses of special interest, between dural and extradural arteries, are with those of the orbit. Such connections always exist. Often a medidural branch enters, through either the sphenoidal foramen or some special opening, and supplies the external wall, even substituting partly or wholly the lachrymal artery, or a branch of the lachrymal may take the reverse course. Very rarely the medidural arises directly from the ophthalmic (Zuckerkandl, four cases, Hulston, one), and then passes by the sphenoidal fissure to its usual distribution. This possible origin should be borne in mind in the rare operation of tying the medidural at the base of the skull.

II. INTRINSIC ARTERIES (or those of the pia and brain substance).—In removing the brain from the skull we sever at its base the four arteries which suffice for its entire blood supply. These are, anteriorly, the two carotids entering through the carotid foramen and canal, posteriorly, the two vertebrals entering beside the foramen magnum. By means of communicating branches at the base of the brain—the vertebrals having first united, and their common basilar trunk having divided into the two postcerebrals—the primary vessels combine to form the circle of Willis. From this practically all and only the *cerebral* arteries emanate. Previously, however, several branches are given off by the vertebrals and basilar; while the carotid yields only the ophthalmic. The latter is said always to originate before any of the cerebral branches, and some millimetres before the bifurcation of the cerebral carotid.

The Vertebrals and Basilar supply in their course the organs of the posterior fossa, viz., cerebellum, pons, oblongata, and their adnexa. In approaching the distal border of the pons the vertebrals unite to form the mesal basilar. This is occasionally divided within by a septum, or separates into two vessels which soon reunite. The basilar lies in the median sulcus of the pons, directly on the basilar process of the occipital bone ; opposite the central border of the pons it ends in the two postcerebrals. Only occasional variations are attributed to the vertebrals: (1) absence of one, the existing vessel being joined by a branch from the opposite carotid; (2) both may join the basilar on the same side; (3) or one may be represented by two or three branches before entering the formation of the basilar trunk.

The lateral branches are:

1. *Postcerebellar*, the largest offshoot of the vertebral. It passes around the oblongata, beside the pneumogastric nerve, to supply the extremity of the cerebellar lobe as far as the median line, the subvermis and adjacent surface, and the plexus of the metepicœle.

2. *Recurrent Spinal Twigs*, also from the vertebral, are given as follows by Kadyi: Immediately after the vertebrals traverse the dura there arises from each a 1 mm. thick branch (dorso-myelic), which, after giving up twigs to the restiform body, descends along the dorsal border of the lateral columns of the cord. This is homologous with other branches entering by the dorsal nerve roots. Sometimes this arises from the vertebral in common with the postcerebellar.

Near the union of the vertebral to the basilar there arises—usually one on each side, though unequal—the myelic branch for the ventromyel. These two, however, either soon or oftener after entering the spinal canal, combine to form the azygoid ventro-myelic artery. They are thus continuous and homologous with the other myelic arterioles coming in along the ventral nerve roots.

A full consideration of the minute details of the arterial distribution in the oblongata is given by Adamkiewicz (*vide* Plate XVII.). These vessels come wholly from the upper (intracranial) part of the vertebrals as they cross the ventral surface of the oblongata.

The main facts regarding the three classes of secondary or nutrient arterioles (external or surface vessels) he accepts from Duret: 1. The radicals, direct from the vertebrals, supply the outgoing nerve roots (facial, acoustic, glosso-pharyngeal, vagus, accessorius, and hypoglossus). 2. The nuclears, at right angles from the one or two dorso-myelics in an extent of 3 to 4 cm. These penetrate the median fissure, at the bottom of which they form a kind of sagittal leader, and end beneath the floor of the metepicœle (fourth ventricle). 3. Arteries for the other portions of the oblongata (olivary bodies, pyramids, corpora restiformia), in part at least from the myelics.

Moreover, on the oblongatal surface is a rich network of vessels. The ventromyelics opposite the oblongata give off a multitude of twigs that take a very sinuous course and soon settle into the furrows. For the dorsal surface of the oblongata there is no external supply until below the calamus—upper end of myel. Its source is the dorsomyelics. These latter, at the first cervical roots, turn caudad between the accessory nerve roots (nearer the dorsal), and when at the level of the fourth or fifth cervical roots they end by also anastomosing with vessels of lower origin.

From the middle portion of the vertebrals, between the ventro- and dorso-myelics, arise the largest branches (subcerebellars), but these dodge the oblongata and are wholly for the cerebellum.

Topographically, Adamkiewicz distinguishes three sets of finer or nutrient arterioles (internal or substantial vessels) after the manner of the myelic supply.

(1) Ventro-fissurals, relatively large, dividing in the ventral commissure into two branches, one to each side for the corresponding ventro-mesal cinerea. In the oblongata these supply principally the pyramidal tracts and decussation, lemniscus, interolivary tract, raphé, and the

following nuclei—gray dorsal columna, n. pyramidalis, n. arciformis, oliva, and hypoglossus.

(2) Dorso-fissurals, of course only caudad of the calamus. These divide at the dorsal commissure into two border vessels, and are for the substance of the dorsal columns, nucleus gracilis, accessorius centre, and casually the hypoglossus.

(3) Coronal, radial, or lateral system. These are very numerous, penetrate the alba from all sides (excepting of course the metepicœle), and in part reach the subjacent cinerea to then help form its mass of capillaries. A subclass here—nuclear arteries—consists of six to eight relatively large twigs entering the angulus restiformia olivaris and running parallel toward the middle of the floor of the metepicœle, to supply principally the centres for glosso-pharyngeus, vagus, hypoglossus, and acusticus. The following parts receive these radial or lateral affluents—the ventral columns, lateral nuclei, lateral cornu, caput of substantia gelatinosa, nuclei cuneati gracilis, arciformis et pyramidalis, and the oliva itself.

3. *Medicerebellar*, usually from the basilar trunk. This passes along the middle cerebellar crus to the preventrad surface of the respective cerebellar hemisphere, including the flocculus.

4. *Transverse* branches, three or four in number. These are parallel and accessory to the preceding.

5. *Auditiva Interna.* Starts like the last, but passes to the internal auditory meatus and structures of the inner ear.

6. *Ponticular* branches. These immediately enter the pons perpendicularly, and supply its substance. They represent true terminal arteries (Heubner), quite comparable to the perforants of the cerebrum. From the importance of the tracts supplied they have likewise great interest to the pathologist.

7. *Supercerebellar.* This starts near the end of the basilar, passes outward along the front border of the pons, winds around the crus cerebri near the optic lobes, and is distributed to the supervermis and general dorsal surface of the cerebellum. It also supplies the post-optic arteries.

The basilar branches all emanate at practically a right angle to the mother trunk. Those going to the surface anastomose much more freely than do the cerebral arteries. Accordingly Heubner found the pia districts of single arteries much less definite over the cerebellum than over the cerebrum. Moreover, the branches of the two sides communicate dorsad across the median line; this is explained by the development of the cerebellum from a single median vesicle. The only communication between this system of vessels and the cerebral—except through the basilar trunk—is by small branches of the precerebellars and postcerebrals across the crura cerebri.

Circle of Willis.—The carotid ends at the outer angle of the chiasma in two main branches, the pre- and medi-cerebral arteries. At about 1 cm. in front of the chiasma the two precerebrals are connected by the precommunicant. From either the medicerebral or the carotid passes the postcommunicant to the corresponding postcerebral. Hence the circle (or polygon) of Willis is made up by one precommunicant, two precerebrals, two medicerebrals (or two carotids), two postcommunicants, and two postcerebrals. This is the classical arrangement; from it, however, there are frequent and important deviations. Professor Windle found that it held in only 76, or, overlooking any disproportion in the postcommunicants, in 119 out of 200 cases. Only in the apes do the vertebrals nearly equal the carotids. In man, Ehrmann, from 157 measurements, found that very constantly the basilar trunk was equal to one carotid (*i.e.*, furnished one-third of the brain supply). The communicants are not simply to re-establish a circulation in case of obliteration, but they normally act to equalize pressure in the local vessels. When this circle is complete and of normal structure, an adequate collateral circulation is established after occlusion of any one part. From this circle and the first few centimetres of its branches originate a multitude of arterioles passing to the basal ganglia and adjacent structures.

Dercum offers "A Collection of Anomalies of the Circle of Willis" (*Journal of Nervous and Mental Diseases*, 1889, January), and J. H. Lloyd (*Ibid.*, 1890, p. 225) gives such a case of a type described by Duret (right vertebral absent, both precerebrals from left carotid, etc.). St. John Bullen (*Journal of Mental Science*, 1890, January, p. 33) bases the following statements on the examination of 1,565 brains (from the insane), but holds statistics too uncertain. Arterial variations occur much oftener in general paralytics than in those dying of other forms—this applying equally to all segments of the circle of Willis.

The components of this circle and their branches:

The Precommunicant.—This is a transverse branch beneath the rostrum, from 1 to 2 mm. in size, connecting the two precerebrals, and forming the anterior side of the circle. Windle found it normal in 159, double in 14, incompletely so (forked at one extremity) in 6, triple in 1, absent in 8, and associated with union of the precerebrals in 2. Wilder notes the latter condition in 6 out of 7 cases, and Starr in 2 of 14. Duret says that when double one is of normal size, the other very small. Its place is sometimes supplied by a fasciculus of small twigs. The precommunicant, Bullen finds, may be absent, or merely rudimentary, or double. Its branches—more numerous when the communicant is unusually long—are:

1. The *Termatica*, a mesal vessel at its origin. Wilder found this present in all of seven brains examined. "It usually divides soon into a right and left portion, which supply respectively the cinerea forming the surface of the triangular area ventrad of the genu and rostrum, and then extend around the genu to the dorsal aspect of the callosum." Windle notes it in nine of his cases. It passed along the longitudinal fissure for two-thirds of the length of the callosum, and divided into branches supplying the opposed surfaces of the hemispheres. When the communicant is wanting, this vessel may start from the junction of the precerebrals.

2. Small retrograde rami to the lamina of the chiasm.

3. Arterioles which plunge into the callosal rostrum, and very often one or two considerable branches completely perforating the rostrum and ramifying on the crura of the fornix, the anterior commissure, and the septum.

The Precerebral (*vide* Plate XVI. and Fig. 818, 3).—This at its origin is almost perpendicular to the carotid. Often the artery of one side is larger than, and partly substitutes, that of the other side. Windle found it normal in 181 of 200 cases. In 2 the right was absent, its place being partly supplied in one by twigs from the right medicerebral, in the other by a small branch from the carotid. In 1 the right was double the size of the left; in 1 the two united to a single trunk; and in 8 they united for a short distance, six times replacing and twice accompanying the precommunicant. Either precerebral may, according to Bullen, (1) be replaced by two small trunks; or (2) be absent, its region being supplied by branches of the opposite artery.

The short oblique portion, dorsad of the optic nerve, between carotid and precommunicant, represents part of the circle of Willis. This portion may give off the following branches: 1, Arterioles to the optic nerve of the same side. 2. Lateral arterioles to the neighboring convolution and the callosal rostrum. 3. When, from premature division of the carotid, the precerebral goes over a longer course, it much oftener gives large twigs to the caudate (*preperforantes*). Duret says that these branches take one of two courses. In one they penetrate almost within the expansion of the olfactory nerve, perforate the callosum at its junction with the lower part of the caudate head, and divide into five or six almost subependymal ramifications not extending beyond the first 2 cm. of the caudate. In the other, one or two arterioles, of about 1 mm. diameter, follow a retrograde course of 3–4 cm. to the preperforated space beneath the caudate, to which latter exclusively they are distributed.

From the precommunicants on, the precerebrals run side by side around the genu and caudad at the bottom of the longitudinal fissure. After giving off the first few branches the main trunk may divide into three branches, as stated by Duret, whose description is largely followed; or several successive branches are given off, as in the accompanying plate. Together, they supply the inner two-thirds of the ventral surface of the frontal lobe, the anterior four-fifths of the opposed surface of the hemispheres, the callosum (largely), and a portion of the convexity.

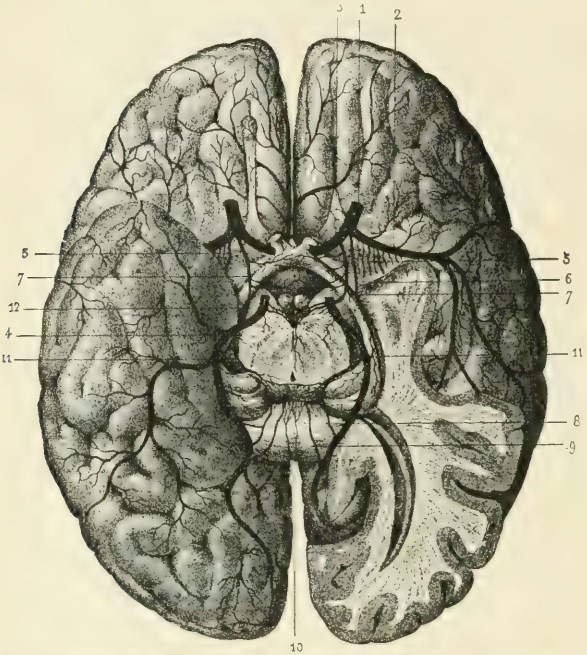

FIG. 818.—Arteries of the Base. (After Duret.) 1, Carotid; 2, medicerebral; 3, precerebral; 4, postcerebral; 5, preperforants (striate arteries); 6, prechoroid; 7, postcommunicants; 8, postchoroid; 9, medichoroid; 10, callosals (termination of precerebrals); 11, medioptics; 12, prethalamic (postperforants). The carotids are drawn frontad to show the preperforants. The left temporal lobe is cut away, exposing the medicerebral trunk at the bottom of the Sylvian fissure, and also its branches crossing the insula.

1. *Subfrontal* twigs, to the olfactory groove and region as far as subfrontal sulcus. 2. *Prefrontal* branch, to mesal surface of superfrontal and convex surface of superfrontal and part of medifrontal convolutions. 3. *Medifrontal* branch, to the callosal convolution, and paracentral lobule. After doubling the crest of the hemisphere it terminates about the dorsal extremity of the central fissure. 4. *Postfrontal* branch, to precuneus and the adjacent portion of the convexity, nearly or quite reaching the occipital fissure. 5. *Callosal* artery. This may pass around the splenium to terminate in the pineal gland, and even posterior commissure. It goes to the callosal convolution and vault, perforating the latter and ramifying over the whole extent of the roof of the paracœles.

The Cerebral Carotid (Fig. 818, 1).—As a rule the postcommunicant is a direct branch of the carotid, though it often starts from the medicerebral. In the former case the carotid, from this branch to its termination at the commencement of the Sylvian fissure in the pre- and medi-cerebrals, forms part of the circle of Willis. In this short course a few lateral branches are given off:

1. Arterioles to the external angle of the chiasm. Either these or the *chiasmic* arterioles from the precerebral supply minute twigs to the first portion of the optic nerve. 2. Frequently, one or more of the *perforantes* to the caudate. 3. *Prechoroid* (Fig. 818, 6). This may come from the medicerebral, or even from the postcommunicant; in any case its origin is peripheral to that of the last named. It is directed obliquely caudad along the outer side of the optic tract to attain the choroid plexus in the lateral horn (through the extremity of the transverse or Bichat's fissure). It gives off: (*a*) internal and slightly recurrent branches to the optic tract; (*b*) internal branches for the central part of the outer aspect of the crus cerebri; (*c*) external branches to the uncus (a terminal arteriole, Heubner); (*d*) extremely fine twigs to the two-thirds of the choroid plexus that it is stated to traverse.

In general, Kolisko's work corroborates that of Heubner. In a large number of examinations this vessel was never absent. It has a pretty constant diameter of 0.5 mm. In the fœtus it is relatively very large. In animals (dogs, cats, rabbits) it was regularly present, but arose from the Sylvian. The branch to the uncus was always present, but has free anastomosis in the pia. The branches in plexus and tela also anastomose freely with others near; but those to the brain substance are terminal.

The prechoroid supplies the following parts: The posterior arm of the internal capsule, with the lamina medullaris externa of the thalamus to the level of the upper angle of the midlenticular segment—usually only the posterior two-thirds; the white substance back of the internal capsule as far as the roof of the medicornu; the inner lenticular segment; the uncus; the optic tract (in its posterior half); the lateral choroid plexus; the endyma of the posterior and lower parts of the paracœle; the greater part of the tail of the caudatum; exceptionally the external parts of the upper half of the thalamus.

But the posterior arm of the internal capsule is also in part supplied by the medicerebral and postcommunicant (the anterior third of this part by the latter vessel), the deeper parts by the prechoroid and postcommunicant, and the upper parts (above apex of midlenticular segment) by the Sylvian (lenticulo-optic ramus of Duret).

Circulatory disturbances in the supply territory of the prechoroid cause opposite hemiplegia by softening in the posterior segment of the internal capsule, involving the pyramidal and cranial-motor tracts.

Hemianæsthesia, hemianopsia, and hemianosmia may likewise follow closure of the prechoroid, but are usually headed off by collateral supply.

When the postcommunicant is large, its blocking may cause opposite facial and hypoglossal paralysis, since these tracts traverse the front part of the posterior arm of the capsule.

The Medicerebral (*vide* Plate XVI. and Fig. 818, 2).—The

EXPLANATION OF
PLATE XVII.

EXPLANATION OF PLATE XVII.

Arterial Supply of Oblongata (from Adamkiewicz), Enlarged Six Diameters.

Fig. 1.—At Decussation of Pyramids.

Hs, Dorsal Column
Ng, Nucleus gracilis
Nc, Nucleus cuneatus
Sgc, Substantia gelatinosa centralis
Ccp, Caput cornu posterioris (aut tuberculum Rolando).
XII, Root of hypoglossus
Vr, Remnant of ventral column.
Prk, Decussation eminence
Py, Pyramid
g, Boundary between Py and Vr.

S, Arteria sulci
Sa, A. sulci (at deeper layers).
Acc, Aa. centrales cornuum anteriorum
Aca, Aa. cornu anterioris.
Anl, A. nuclei lateralis.
As R, A. tuberculi Rolando.
Anc, A. nuclei cuneati.
Ang, Aa. nuclei gracilis.
F, A. fissuræ.

Fig. 2.—Opposite Middle of Metepicœle.

H, Hypoglossus nucleus.
Va, Post. vagus nucleus
Po, Ponticulus (velum medullare posticum).
Gl, Glossopharyngeus nucleus.
Ac, Acusticus nucleus.
Lb, Longitudinal bundle.
(Krause's respiratory fasciculus.)
Cr, Corpus restiforme.
X, Ant. vagus nucleus.
IX, Root of glossopharyngeus.
Aro, Angulus restiformio-olivaris.
O, Oliva
No, Nucleus pyramidalis.
Ozs, Interolivary tract.
R, Raphé

Py, Pyramid.
Na, Nucleus arciformis.
S, Arteria sulci.
Sce, Affluents to external nest-like capillary coils, from sulcus artery.
Sci, Affluents to inner same.
Aoli, Sublateral olivary artery.
Aso, Olivary ramus from sulcus artery.
Aoli, Subolivary arteries.
Aolm, Medilateral olivary artery.
Aols, Super-olivary artery.
An, Arteries of the nuclei (glossopharyngeus, vagus, hypoglossus).
Vn, Nuclear vessels (glossopharyngeus, acusticus).
F, Arteria fissuræ.

Fig. 3.—Longitudinal Section through Olivary Body.

O, Oliva
Br, Pons

Aoli, Aa. olivæ laterales inferiores.
An, Aa. nucleariæ

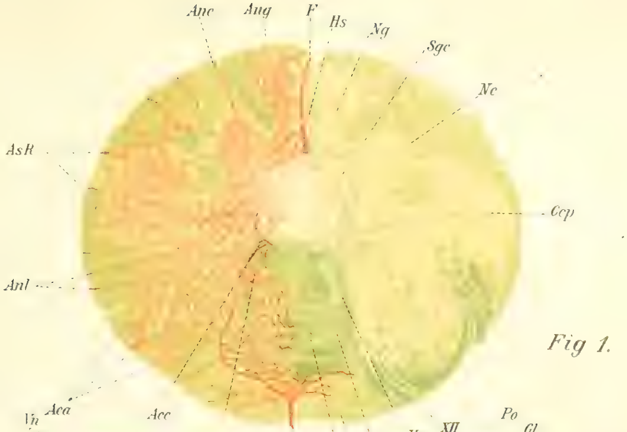

Fig 1.

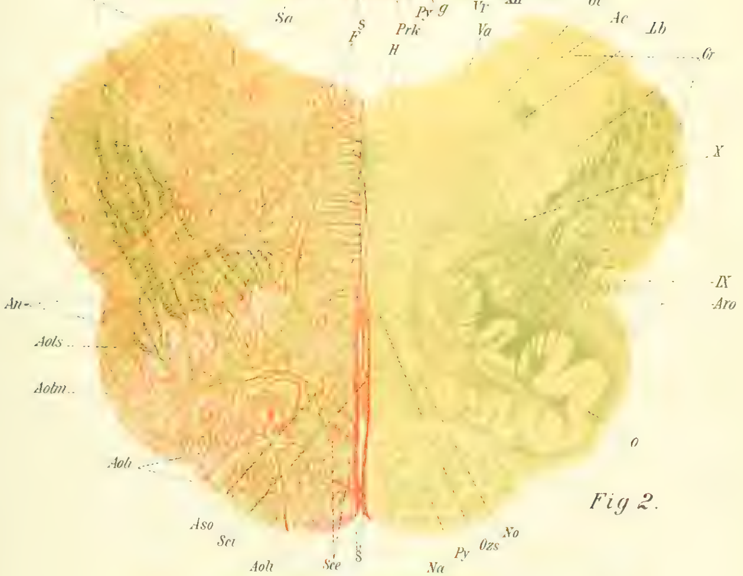

Fig 2.

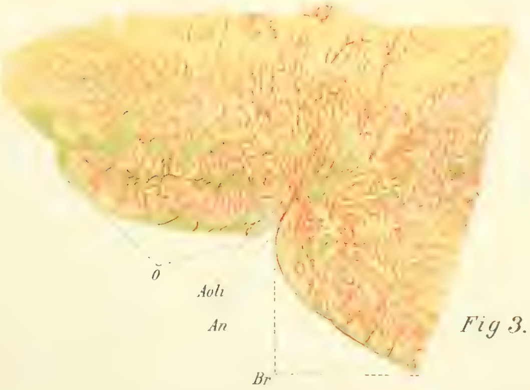

Fig 3.

Arterial Supply of Oblongata (from Adamkiewicz.)

vessel represents the most direct continuation of the cerebral carotid. It lies at the bottom of the Sylvian fissure, as do also the primitive portions of its larger branches as they spread out over the insula. When the postcommunicant starts from the medicerebral, the previous short (4–6 mm. long) portion of the latter participates in the circle of Willis. No branches are assigned to this part.

The medicerebral in its further course yields two classes of branches: (*a*) direct, perforating, or nutrient arterioles; (*b*) large and small pia arteries.

(*a*) A few perforantes (Fig. 818, 5, 5) from the earlier part of this artery may pass directly to the caudate head, with those described under precerebral and mentioned under carotid. But the main group from this source take a somewhat different course, and, as stated by Heubner, are often detached from the trunk farther out in the fissure. These have been divided into two sets. The first to leave the trunk—*lenticular arteries*—are the finer, and are similar in deportment to the preceding, except that they go to the first and second segments (apex) of the lenticular nucleus. The second, coarser set runs along the base of the lenticular nucleus on the limit of the external capsule. A portion of these pass caudad and dorsad to the thalamic extremity of the lenticular nucleus, and terminate in the thalamus—*lenticulo-thalamic arteries*. One arteriole, noticeably larger than any of the others and the frequent source of hemorrhage in this region, passes dorsad and mesad to the third segment of the lenticular, where it gives off many side twigs, and finally divides into four or five terminal branches, supplying also the adjacent internal capsule, etc. Two or three accompanying arterioles extend toward the third segment, and may attain the tail of the caudate. Collectively these are termed *lenticulo-striate arteries*.

A further group might be made of the small direct vessels traversing the insula to gain and supply the claustrum; as this is, however, a derivative of the external gray layer, these twigs more nearly correspond to the general cortical and albal arterioles.

Of the perforantes as a whole, it may be said that they all emanate at right angles from the inner side of the mother vessel. Their size varies from 0.5 to 1.5 mm. They immediately enter the brain substance, only occasionally dividing, and never anastomosing before doing so. They usually run a further short course before branching. The ultimate distribution of each is pencil-shaped. They are destined to supply the central gray nuclei and the capsules, notably the inner. They are all true terminal arteries, without any anastomoses either between themselves or with other arteries. According to the French school, even their finest capillaries do not connect, but on this point the Germans teach otherwise.

(*b*) Pia branches of the medicerebral. After a course of 1 to 2.5 cm. the main trunk, either at one stroke or successively, divides into several large branches. 1. Previously, however, there are usually a few small rami for the adjacent borders of the frontal, and especially the temporal, lobes (see Plate XVI.).

2. *Frontal* branch. This is generally the first large ramus. Like the succeeding, it runs some distance deep in the sulcus and subdivides often, at least before appearing externally. It is especially destined for the subfrontal convolution. It supplies the orbital surface of the frontal lobe external to the orbital fissure, and the convexity dorsad to the middle of the medifrontal gyrus, caudad to the precentral sulcus. Duret found a very constant corresponding artery in several species of animals.

3. *Preparietal.* This nourishes the precentral and adjacent extremity of medifrontal convolutions, and may by an early branch include the postcentral also.

4. *Mediparietal.* This may gain the fissure of Rolando to supply not only the postcentral convolution, but dorsad a portion also of the precentral. It may also reach the adjacent parietal region.

5. *Postparietal.* This is a large branch in the horizontal Sylvian fissure. Its ramifications do not extend beyond the parietal or occipital fissure, but may pass beyond the supertemporal.

6. *Temporal.* This is included under the last by many, but it is often an early and large branch of the medicerebral. By its numerous considerable subdivisions it then covers practically the whole external temporal surface. At least the supertemporal convolution and much of the meditemporal are regularly supplied. Its distribution extends nearly to the suboccipital convolution.

There is no special artery for the insula, but it receives several small branches from the preceding as they cross it.

The Postcommunicant.—Connecting the pre- and post- (carotid and vertebral) systems. They start from the carotid or medicerebral, and run directly caudad to inosculate with the corresponding postcerebral at 5–12 mm. from the latter's origin. They pass ventrad of the optic tracts and also encounter the crura cerebri. In size and occurrence these vessels are variable, and frequently unsymmetrical. The left is more often the smaller or even absent, though some filiform anastomosis from a corresponding branch of the carotid usually does exist. As a very large branch from the carotid, especially the right, it may replace the corresponding postcerebral wholly or in part, or conversely; a large left communicant has been observed to arise from the postcerebral and supply the same medicerebral. Aside from disparity in size (43 times) the postcommunicants were normal in 175 of Windle's cases. Excepting slight anastomosis, both were absent in 3 cases, the right in 9, the left in 13. In 7 both were very small; in 28 the right was much larger than the left; in 15 the reverse.

Anomalies, says Bullen, are more common in the postcommunicants than in all the others. Of these vessels, either (1) may be absent; (2) may be replaced by a branch from the subcerebellar, internal carotid, postcerebral, or two small nutrient branches respectively from the last two vessels; (3) may supply unusual regions; or (4) may be unconnected with the carotid system.

This vessel gives off laterally pia branches, (*a*) internal, (*b*) external, and (*c*) inconstant penetrating rami.

(*a*) 1. Chiasmic branches to the caudal side of the chiasm. 2. Twigs to the tuber cinereum and infundibulum, a descending ramus supplying the pituitary body. 3. Two to the mammillary bodies.

(*b*) 1. To the optic tract. 2. To the cerebral crura. 3. Often considerable branches to adjacent temporal gyri.

(*c*) 1. *Prethalamic Artery* (internal and anterior optic of Duret). It penetrates between the tuber cinereum and mammillary bodies, and ramifies in the more anterior part of the aula, on the walls of the infundibulum, etc. 2. Medithalamic artery (posterior internal optic). At times large, it enters the postperforated space and passes directly dorsad near the inner thalamic wall, to which and the gray commissure it is distributed. This vessel comes as often from the postcerebral as from the postcommunicant. The prethalamic may also have the same origin.

The Postcerebrals, from the end of the basilar to the postcommunicants, complete the circle of Willis. This part furnishes: (1) three or four arterioles to the internal aspect of the crura cerebri, supplying its basal layer, the locus niger, etc.; (2) little branches entering the thalamus through the postperforated space. These accompany, and often include, the above-described medithalamic artery.

Windle found the postcerebral arteries normal in 173 cases. The vessel was derived from the carotid instead of the basilar in 11 cases on the right, 9 on the left, and 4 on both sides. There were 2 postcerebrals on the same side—the smaller from the basilar, the larger from the carotid—in 3 cases: 1 on the right and 2 on the left. Either of the postcerebrals may (Bullen) (1) be absent; (2) be a branch of the carotid system; (3) be replaced by a large postcommunicant; or (4) be replaced by two thread-like vessels from the basilar.

This trunk, in passing around the crus, describes a kind of semicircle, directed toward the transverse fissure. Dorsad of the crus, at about 1 cm. from the optic lobes, it turns latero-caudad to gain the calcarine fissure, where it breaks up to supply the basilar postcerebral region. From its crural portions it supplies, besides other branches, nearly all the nutrient arteries of the cœlian walls.

1. Little twigs to the outer part of the crus, penetrating almost immediately. Instead of several in the thalamo-crural sulcus, there may be a single larger one, parallel to the main stem.

2. The fairly constant *Medioptic* (median quadrigeminal), giving fine offshoots in its course to the crus, and terminating in a bunch of fine vessels in the interval of the optic lobes.

3. *Postthalamic* (so-called posterior and external), two or three, or a single larger one, starting midway from this portion of the postcerebral, and following the crus to enter the thalamus between the geniculate bodies.

4. *Geniculate*, emanating directly, or from the thalamic.

5. *Postchoroid* (posterior and lateral), starting near the optic lobes, and entering between the layers of the velum. It always divides into two principal rami: a lateral one for the third of the choroid plexus not supplied by the prechoroid artery, *i.e.*, for the plexus over the thalamus; the other more median one for the velum (*ramus velaris*).

6. *Medichoroid* (posterior and median choroidal), from the postcerebral at its nearest approach to the median line. It courses beside the conarium, to which it yields some rami, and immediately divides into two branches, one to the velum of the aula, the other exclusively to the choroid plexus of the same cavity.

The choroid plexi and velum represent a double layer (fold) of the pia, within which the cœlian arteries and veins course. Duret states that in all the cœles the arteries to the velum are distinct from those to the plexus, often even from their origin at the postcerebral, and always at their entrance into the corresponding cavity, and that they never mingle in their distribution. From the velar arteries are detached a multitude of little arterioles, which penetrate the thalamus 1 to 1.5 cm. They have the arrangement of cortical arterioles, and are pencillated. The two velar branches terminate in the head of the caudate, either simply subependymal or passing deeply into its substance. The velar branches to the aula emit little arterioles laterally at intervals of about a millimetre. These penetrate perpendicularly the adjacent wall. They supply also the posterior and gray commissures, and terminate in a fine pencil in the anterior commissure. The plexus arteries, on the contrary, do not usually participate in the nutrition of the cœlian walls. They divide into four or five long parallel branches from which little arterioles pass into the plexuses, properly speaking. They enter the little tufts by their base, and form very attenuated and sinuous capillary meshes. It has been suggested that they are the remains of former branches ramifying in the embryonic cœlian pia, and that they became coiled up when this membrane retracted.

7. *Preoptic* (anterior quadrigeminal), very short, coming from the most median part of the postcerebral, or from some branch of the latter. It forms a very delicate pencil over the preoptic body. This makes the third pretty constant pair of optic arteries, as these lobes are very vascular. They have some anastomoses across the median line.

8. Artery of the cornu Ammonis, oftener from some branch of the postcerebral than arising directly. It does not ramify on the cœlian surface, but passes between the Ammonshorn and the hippocampal convolution, to traverse the cortex in the manner of external arteries.

9. Variable branches to adjacent temporal gyri.

Final Divisions of Postcerebral.—These may be brought under three general heads (see Plate XVI.).

1. *Pretemporal* branches to the uncus in part, and the basal surface of the temporal lobe as far as the border of the convexity, except the third nearest the apex of the lobe, which is supplied from the medicerebral.

2. *Posttemporal* to the basal surface of the occipital lobe, including a variable amount of the adjacent temporal region, and doubling the border of the convexity to supply a little of the external occipital region. The hippocampus may be supplied from the parent stem, or from either 1 or 2.

3. *Occipital* artery. This runs along the calcarine fissure, sending a large branch through the occipital fissure; it supplies the cuneus and general median surface of the postcerebral lobe, and a considerable strip of the adjacent occipital convexity. Spitzka says that an artery large enough to cause fatal hemorrhage enters the gray and white of the right occipital lobe.

GENERAL FEATURES OF THE ARTERIAL SUPPLY.—The distribution of each primary trunk includes: (*a*) basilar or nuclear branches; and (*b*) pia or cortical branches.

(*a*) These are the pre- and post-perforating and cœlian arteries, arising in part from the circle of Willis. They supply the central ganglia, cœlian structures, and in part the centrum semiovale. To the same class belong the direct arterioles from the basilar to the nuclei in the pons. Excepting occasional and unimportant anastomoses, these are all true terminal vessels. They divide within the brain substance at an acute, and not a right, angle.

(*b*) The pia branches or divisions as described are only averages, complementary variations therefrom always being present; though it is claimed that while "their origin is often very variable, their distribution is constant." The larger arterial trunks correspond to the main fissures. To a marked extent it is true that the same branch does not supply both sides of a sulcus. Branches usually leave the parent stem at almost or quite a right angle. Some writers try to show a freer supply to the left hemisphere. Duret's attempted correlation of arterial distribution and physiological function was at least premature (1877) and faulty.

Anastomoses.—The basal circle of Willis comprises all the communications readily demonstrable on the uninjected pia arteries of the cerebrum. Only within this circle and over the optic lobes are there any minute connections across the median line of the hemispheres.

There has been a dispute as to the extent to which the ramifications of adjacent branches on either hemisphere are connected. Duret, after numerous, varied, and evidently careful examinations, says: "Never have we found an anastomotic network in the pia." He also notes the frequent superposition in the pia of fine arterial ramifications. Nevertheless he found considerable individual differences, and regularly some fine (0.2 to 0.25 mm.) communications, especially at the periphery, *i.e.*, between adjacent territories of distribution. On p. 927 he acknowledges that in the great majority of cases, owing to anastomoses, "however rare and unimportant," softening from occlusion of any of the large basilar trunks spares the peripheral parts of the artery's territory. In the four-months fœtus he found abundant fine anastomoses. Heubner (p. 174), on the contrary, says: "The chief [pia] branches end in a kind of communicating canal system or reservoir, which is spread out in the shape of a tubular net over the whole surface of the brain." By injecting "under weak finger pressure" he found plentiful anastomoses up to 1 mm. in diameter. Heubner's description harmonizes with that of older writers, and is corroborated by Lucas, who by sufficiently penetrating injections was able to demonstrate an abundance of communicating arterioles up to 0.25 mm. (*vide* Plate XVIII., Fig. 2). It remains true, however, that when the communicants of the circle of Willis are poorly developed, the peripheral anastomoses are, in a large number of cases, incapable of substituting them.

Direct or Nutrient Arterioles of the Convolutions.—These emanate at right angles from the pia branches, of all sizes. They penetrate the crests of the convolutions perpendicularly, the inclined surfaces obliquely. They are innumerable—scarcely more than 1 mm. apart. According to size and distribution there are two classes:

1. Cortical, 0.05 to 0.03 mm. in diameter. The finer stop in the cortex proper; the others go to the boundary of gray and white. The capillary network from these rami has been divided into three somewhat differently characterized layers, each parallel to the rolling surface.

2. Albal (arteriolæ longæ), 0.08 to 0.14 mm. in diameter. These are almost rectilinear, can be followed a distance of from 3 to 4 cm., and branch at an acute angle. They supply a considerable portion of the centrum semiovale. One often passes down along the axis of the convolution. A group of five or six at the bottom of a fissure (in section) diverge on entering. The capillary network of the albals is more elongated than that of the corticals, and accompanies the fasciculi of nerve fibres.

Both classes anastomose freely in their finer branches, though in general pencillate.

From the anatomical arrangement it is believed that the intravascular pressure is less in the gray than in the white substance.

It has been claimed by many that the thyroid gland acts as a safety diverticulum to the cerebral supply; and furthermore, that the lack of this regulator explained the occurrence of so-called cachexia strumipriva after removal of that gland; but any such special function of the thyroid is at least not proven.

Width of Brain Arteries.—To make a relative estimate of the capacity of the arteries at the base, Bevan Lewis ("Examination of Brain," 1882, pp. 20–22) determined their average diameters in 45 cases (insane). That of the vertebral was, r. 3.147 mm., l. 3.42; of basilar, 3.82; of postcerebral, r. 2.658, l. 2.56; of carotid, r. 3.951, l. 4.02; of medicerebral, r. 3.133, l. 3.55; and of precerebral, r. 2.73, l. 2.66. The sectional areas are of course proportional to the square of these diameters. As a rule, the united areas of branches equal very nearly the area of the parent trunk—excepting the preponderance of the vertebrals over the basilar (22.4 to 14.8).

Löwenfeld has found that the relation of the artery width to the brain weight is, even normally, somewhat variable, and that often, though not by any means in all cases, the width of the brain vessels rises and falls with the width of the aorta; moreover, that not rarely abnormally small brain arteries occur in otherwise well-developed arterial systems. He also made out a difference in the two sides, the left carotid being usually wider than the right.

Pressure in the Brain Arteries.—A further matter, noted by St. John Bullen (*loc. cit.*), may partially indicate the relative pressures in the main brain arteries. He remarked atheroma of the basal vessels in 410 of 1,565 autopsies, or 26 per cent. of the total. It was present to a considerable extent, either generally dispersed or in special trunks only, in 175 cases, and to a less extent in 235. The relative frequency by location was: medicerebral, 38 per cent.; basilar, 30 per cent.; postcerebral, 21 per cent.; carotid, 10 per cent.

Mendel (1891) has found experimentally that the pressure in the cortical arteries is materially less than that in the carotids, while that in the striatal arteries is not materially less. This he attributes to the fact that the latter are terminal vessels, though it is doubtless quite as much due to their less circuitous supply. He further thus explains the frequency of hemorrhage in the striatal region.

Tedeschi's conclusions regarding the brain arteries refer in part to moot points, but really contain nothing new and are deceptive in statement.

VEINS.

The venous passages of the brain and its membranes include:

I. The dural veins.
II. The intrinsic veins, or those of the brain proper.
III. The sinuses.
IV. The venous exits from the skull.

All the intrinsic and most of the dural veins discharge into the sinuses, or appendatory spaces, which in turn convey the blood to the exits. Otherwise these two sets of veins are separate systems, not interanastomosing, unless occasionally near their mouths. The intrinsic veins without exception have thin, readily collapsing walls, while the sinuses are held open by the firm enclosing dura. In general it may be stated that *the walls of all these vessels are devoid of muscular elements*, though occasional unstriped fibres have been observed in the intrinsic veins. From this absence of actively contracting fibres, it follows that these vessels play a merely passive rôle in the encephalic circulation. The encranial veins, like the external veins of the head, are devoid of true valves. However, at the orifices of the diploë veins (Dupuytren, Langer, doubted by Trolard) and in the ophthalmo-dural vein, valves *may* occur. It has also been claimed that the supercerebral veins in part present a valvular arrangement at their discharge into the longitudinal sinus. The general impression that valves never occur in any of the veins above the common jugular is therefore incorrect.

I. VEINS OF THE DURA (including those of the diploë).—These are many in number, but all of small size. They anastomose so freely that they might almost be denominated a plexus. In position they are comparable to the plexus venosus existing between dura and periosteum of the spinal canal. In their ultimate distribution they form two vascular nets, according to Langer, one in the outer, the other in the inner, layer of the dura. The beautiful, almost regular, interlacing of the former, figured by Langer from the fœtus, the writer is able to corroborate. By means of small veinlets penetrating the inner plate of the skull, the dural veins communicate extensively with those of the diploë. They include:

1. *Medidural*, or *Venæ Comites*, accompanying the medidural artery and its branches. The two on either side of an artery repeatedly connect with each other and with neighboring veinlets. The largest pair is about the common trunk of the artery. One of these passes externally through a basal foramen to the pterygoid veins. The other ends in the medicerebral vein or its temporal sinus, or directly in the sphenoidal or cavernous sinus, with which latter it usually at least connects. The diploic canals have some special openings into the larger medidural veins.

2. *Superdurals.* These appear in part as direct continuations of the preceding, and then are double. They pass to the longitudinal sinus, largely through the intermediation of its lateral spaces. Labbé suggests that the supra- and medi-dural veins may constitute a small collateral path between the long sinus and basal conduits.

3. *Falcial Trunklets* (Fig. 819, *k*), running to the longitudinal sinus and to the falcial sinus when present, otherwise to the tentorial. The tentorials go to the lateral and tentorial sinuses, also in part by way of the parasinual spaces.

4. The numerous veinlets for the other dural arteries, *e.g.*, in the occipital fossa, have a more independent course and end in adjacent sinuses.

Venous Canals of the Diploë, even less yielding than the sinuses. Breschet's description is somewhat modified by Trolard. The diploë is made up of little areolæ. These canalize in any direction, though in general ventrad to discharge near the base. These canals are quite unsymmetrical, and do not increase in size in their course, excepting where there are casual enlargements; areolæ, conduits, and lacunæ are lined with a smooth membrane. Generally the diploë begins to appear about the tenth year, though small straight veins are evident earlier. Resorption of the cancelli goes on continuously, and after fusion of the sutures they may pass from one bone to another. In the aged we find a sort of wide-spaced venous plexus, no longer canals. There are several exterior outlets and numerous interior ones. Even the one through the supraorbital notch passes to the ophthalmic vein and so to the cavernous sinus. Casual mention will be made of most of the special terminations.

II. VEINS OF THE PIA AND BRAIN SUBSTANCE.—From their derivation and discharge, these vessels naturally fall into three classes: A. The supercerebrals, passing to the longitudinal sinus. B. The internal or Galen's system, tributary to the tentorial sinus. C. Basal veins, ending in the various sinuses of the base.

A. The *Supercerebral* veins return the blood from the convexity as far as the Sylvian fissure, and from the median surface of the hemispheres as far as the supercallosal fissure. There may be a slight interval between the frontal set and the others, or a smaller vein may here occur; otherwise they are all fairly equidistant. There are usually six to eight large trunks on each side. These veins tend to empty into the sinus in pairs. This is less marked in the frontal set. It is most easily demonstrable in the fœtus, owing to the absence of Pacchionian bodies, or thickening, adhesions, etc., at the border of the convexity. The last pair ends in the sinus some 3 to 5 cm. before the torcular. The second or third pair from the last may be somewhat larger than the others, and then represent the so-called anastomotic vein, though its size is quite as much due to the greater width of the brain in this part. Although Labbé says this vein runs along the postcentral fissure, it is probably identical with Krause's fetal *vena sulci centralis.* Moreover, each supercerebral vein is double, also best seen in the fœtus. The two constituent veins are of unequal size, the larger external one coming from the convexity, the smaller inner one coming from the median surface (of hemisphere). They may soon unite to one trunk, but generally, in their further course to the sinus, they lie side by side within a common sheath, and do not lose their integrity as independent conduits until about to open into the sinus. Commonly some of the paired, as well as their constituent double veins, are wanting to complete the diagram.

The frontal set take a course very nearly at right angles to the sinus, or the first of them may even run caudad along the sinus before discharging. They usually spring over to the dura a couple of centimetres away from the sinus. This point has since been more carefully gone over by Mittenzweig. In 200 cases he found 59 in which the presupracerebals (to only 9 in which the postsupracerebrals) jumped over from the piarachnoid to the dura at 3 to 4 cm. from the long sinus —thus favoring their rupture, as he thinks. Farther along the sinus the veins take a more and more oblique course until they at last run forward a distance of 3 or 4 cm., to discharge against the current. At the border of the convexity, or farther out in the pia, the vein makes the necessary bend to approach the sinus as described. It then runs a short distance in the pia, becomes in the fœtus a free trunk for a further short length, and finishes its course in the dura.

Again, the frontal set open at the lateral angle of the sinus, while the others open more and more at the side, and the last quite at the bottom of the sinus, even coming up a distance through the falx.

Toward their field of derivation these trunks pursue an indifferently parallel course. In general, over the cortical area the finest veinlets are richly distributed everywhere, from the bottom of the fissures to the crest of the convolutions.

B. *The Internal System, Tributary to the Tentorial Sinus.*—Along its course this mesal sinus receives only unimportant, mostly dural, veinlets. At its commencement there may be two affluents: (*a*) the falcial sinus; (*b*) the vena Galeni.

(*a*) The inconstant *falcial sinus* also receives only dural twigs in its course, but at its commencement—opposite the frontal border of middle third of callosum—*may* take up a small vein or veins coming from the frontal third of the callosum, and from the bordering convolutions. Labbé calls this the *interhemispheric vein*, and says that the 1 to 2 cm. long veinule bifurcates, sending one branch to either side. A parallel term, *mesolobica*, was given by Breschet to the precerebral vein.

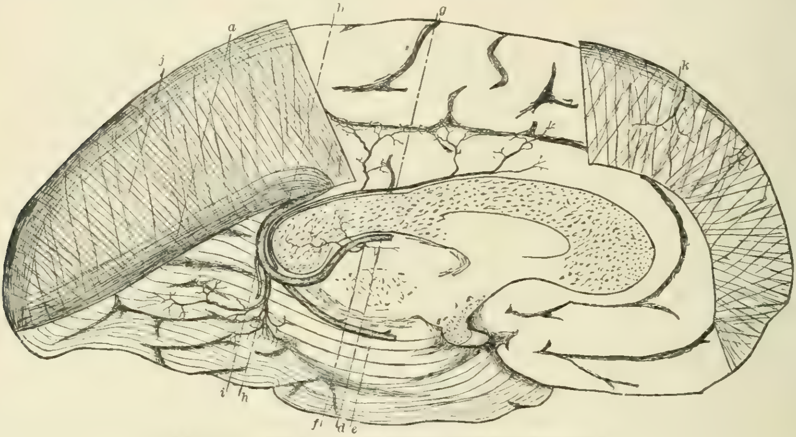

Fig. 819. The Vena Galeni. (From the author's "Veins of the Brain," etc.)

(*b*) *Vena Galeni.* This discharges through a slit in the basal wall of the sinus, just caudad of the free border of the tentorium. The name is now limited to the short (1 cm. long, 6 mm. broad) trunk from the union of the velar veins to the sinus. Within, it is often divided by a longitudinal septum.

The course of Galen's vein and that of the adjacent portion of the velars is very peculiar. The vessels sink a little after crossing the optic lobes, then encircle the splenium, and become subtentorial before ending in the sinus. The latter bears the relation thereto of a tangent to a circle (*vide* Fig. 819).

Galen's vein does not usually receive any lateral affluents. It arises from the union of the right and left *velar veins.* Each of these consists of two portions, a terminal bent part (*portio curvata*, Fig. 820, *c c*) from the conarium to the vena Galeni, and a peripheral, or cœlian, straight part (*portio recta*) from the origin of these veins, opposite the foramen of Monro. The two curved portions start and end together, but midway diverge 0.5 cm.; they receive laterally many large branches. The straight portions run parallel and adjacent, but receive only few and small additions.

The affluents to the portio curvata are largely of cortical origin; (1) v. suboccipitalis; (2) v. supercerebellaris;

(3) v. callosalis; (4) v. subcerebralis; (5) vv. optici et conarialis; (6) v. postcornualis.

1. The *Suboccipital* vein (Fig. 819, *b*) comes from the collateral fissure and median portion of the suboccipital surface of the cerebrum.

2. The *Supercerebellar* vein (Fig. 819, *h*), oftener a single trunk, but occasionally bilateral, empties into the main vein near its termination, or even directly into the sinus tentorialis. It starts from many little branches over the dorsal surface of the cerebellum, the supervermis, and in its further course takes up small veins from the crura cerebri, and at times also from the optic lobes.

3. The *Callosal* vein (Figs. 819 and 820, *g*) (first mentioned by Labbé, 1879, then independently described by the writer in 1884) may be either single or bilateral. It is a small but long vessel, and the only one emptying on the concave side of the portio curvata. Its origin is near the middle of the callosum, and dorsad as far as the callosal fissure. It runs caudad at the bottom of the longitudinal fissure, and curves around the splenium close to Galen's vein. In animals (sheep) its size almost equals that of Galen's vein.

4. The *Subcerebral* (Fig. 819, *e*) is a large vein, though its derivative territory is very variable. It forms by the union of many branches—collectively termed *Prebasal Veins*—opposite the preperforated space. The prebasilars include the first five next following:

(1) The *Precerebral* vein takes nearly the same path, but is too small and uncertain to be well compared to the precerebral artery. Its derivative area is very much less. It comes around the genu to the base, where it passes before the chiasm to the subcerebral vein. The right and left are usually of unequal size, but communicate, though by an insignificant branch compared to the arterial precommunicant. The two veins may also unite before the chiasm and pass to one of the subcerebrals, in which case there are one or more slight connections in front of the chiasm with the other subcerebral vein. This vein receives branches from the genu and adjacent median frontal surface.

(2) The *Olfactory* is a tiny veinule, very constant, and demonstrable as far as the olfactory bulb.

(3) *Subfrontals.* One of these is frequently more developed, and may empty instead directly into the Sylvian or the medicerebral vein.

(4) The *Sylvian* vein, as shown by the writer, is distinct from and a variable complement of the medicerebral vein (*vide infra*). *It lies at the bottom of the basi-Sylvian fissure*, covered up, except near its termination, by the tip of the temporal lobe. It arises in the region of the insula from a great number of radicles. When the medicerebral is poorly represented, the Sylvian may take up twigs from the surface of the temporal and frontal lobes; some of the venæ perforantes pass, as a rule, to this vein. There is here often a group of perforantes, separated from the others and coming from the brain substance caudad of the veins.

(5) The *Venæ Preperforantes* are small, very variable in number, and take a straight course for a short distance before splitting up. They come from the striate nuclei and adjacent frontal albalis. Their radicles approximate those of the precornual veins, yet without observable anastomoses.

(6) The subcerebral vein receives, in its course obliquely across the optic tracts and crura cerebri, several small veinules from the chiasm, infundibulum, mammillary bodies, crura, etc. These anastomose freely with one another, and with those of the other side, thus making an outstretched network over these parts which connect on the one hand with a small network before the chiasm, and on the other with that across the pons. This corresponds in general to what Labbé terms the inferior interhemispheric veins. Frequently there are accessory veinules from the basal temporal surface.

(7) The *Subcornual* vein, in that it comes from the end of the middle horn, is comparable to the prechoroid artery. It is very constant in occurrence, but not in size. Though connected with the choroid plexus of the medicornu, it originates in the cerebral substance, sometimes even from the lateral wall of the postcornu, oftener opposite the caudad border of the thalamus, where branches are received from the albalis lateral to the thalamus or from other directions. In its course along the lateral wall of the horn it receives many accessions, notably from the cornu Ammonis, and as it curves around the end of the horn several twigs from the albalis of the temporal apex.

(8) *Postperforant,* at least one considerable veinule. The post-perforating veins come, according to Hédon, from the cinerea of the walls of the diacœle, and even from the mesal surface of the thalamus. He also claims that in the striate nuclei the perforating veins anastomose with those going toward the cavities and Galen's system. He further recognizes the communications in the medicornu between the choroidal and the infracornual veins.

(9) *Crural* branches, one in particular, can be followed along the crus to the cerebellum.

5. The fine *Conarial* vein and variable *Optic* twigs often end in the supercerebellar vein instead of directly in the velar. They originate in a fine venous plexus over the optic lobes and conarium, which appears to be connected across the crura cerebri with the basal network described above.

6. The *Postcornual* vein is variable, complementary in derivation to the subcornual. It may arise in the albalis near the tip of the occipital lobe, and then runs subependymal along the cornual wall. The parathalamic branches above ascribed to the subcornual, and some from the Ammon's horn, pass often in part to the postcornual. The radiate radicles of this vein are traceable through the albalis nearly to the cortex (Fig. 820, *q*, *q*).

There is frequently another vein intermediary between (7) and 6, emptying into either the subcerebral or the postcornual.

The straight portion of the velar vein in its course through the velum receives the following, all at right angles:

1. The *Splenial* veins (Fig. 819, *f*) are very small, and but two or three in number as they come out through the fornix. They often combine with thalamic radicles and empty as one trunk into the velar.

2. The *Thalamo-Crural* vein, usually one on each side, but sometimes multiple (Fig. 820, *m*, *m*). This begins about the cerebral crus, makes its way dorsad and mesad through the thalamus, and joins the portio recta at about its middle point. It approaches the ventral side of the velar, and hence is but too easily overseen. Neither 1 nor 2 runs any length in the velum.

3. The *Thalamic* veinules are very variable in size, number, and position. They may even be entirely wanting, or run to neighboring veins, *e.g.*, the postcornual. These arise only to a limited extent in the thalamus; they come chiefly from the albalis beyond, running across or a trifle embedded in it. Where one of these is specially large it might be termed the *Transthalamic*.

Opposite or toward the apex of the thalamus, the velar vein is formed by the immediate or mediate union of several small trunks. Most of these are in a cluster coming in laterally between thalamus and striatum; the latter nucleus appears much richer in veins than the former. Of all but the first, the intracœlial course of these veins is subependymal.

1. The *Medicornual* vein (Fig. 820, *l*) takes a sinuous course in the outer edge of the choroid plexus, of about double the actual distance. Its membranous envelopment makes it a counterpart of the pia veins, and hence the actual continuation of the velar, as held by Bell. It begins in the middle horn, where it is said to anastomose with the subcornual. It comes out of the horn with the plexus, bends to follow the lateral thalamic border, and ends in any one of the veins near the commencement of the velar. Meanwhile it receives a multitude of radicles from the plexus, and some that seem to come from the surface of the thalamus.

2. The *Tænial* vein comes from the thalamo-striatal

groove, beneath the tænia. Nevertheless it has few tributaries from the thalamus. This short trunk is made up by three sets of veinules: (*a*) *Striatal.* Of these there are usually two or three larger and several smaller branches, coming from the substance and surface of the caudate, and passing to the tænial trunk or to either of the following: (*b*) A prealbal trend of veinules, passing along the outer cœlian border toward the precornu, and thence largely to the albalis of the frontal lobe. (*c*) An opposite trend, directly caudad, a short distance along the outer cœlian wall, and coming from the lenticular nucleus, the internal and external capsules, and the superimposed portion of the centrum semiovale. Many of these various albal radicles can be followed almost to the cortex; their angles of union are acute.

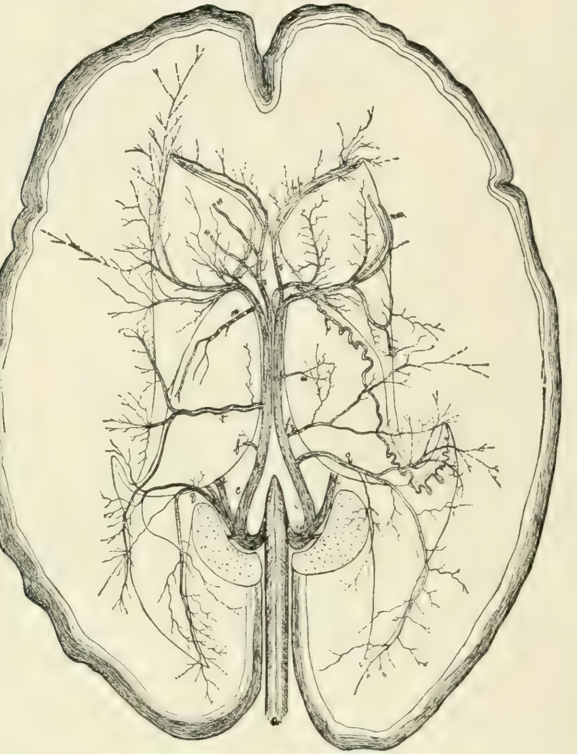

FIG. 820. The Cœlian Veins. (From the author's "Veins of the Brain," etc.)

3. The *Paraseptal* trunk (Fig. 820, *o, o*). This short vessel, with its two constituent *Precornual* veins, is the most direct continuation of the velar. Laterally it receives small *Septal* and *Genual* accessions. There are usually two parallel precornuals (*p, p*). They come from the extremity of the horn and follow its contour around to the septum, or run in the adjacent border of the caudate, though they take up no important radicles from that nucleus. Their multitude of radicles come from the albalis in the basal portion of the frontal lobe, also demonstrable nearly to the cortex.

4. The *Superalbals* (Fig. 820, *n, n*) are commonly two small trunks that appear at the outer border of the cœle, opposite the body of the caudate, cross the latter, and empty through the tænial or paraseptal trunk. They come from the cœlian roof, and the frontal and parietal albalis dorsad of those previously described.

C. *Basal Veins* (Fig. 821).—These do not constitute a system in the sense of having a common point of discharge—in fact, they have already been described in part under Subcerebral Vein. Although they are quite irregular in termination—small veins seem occasionally to end at any point in the basal sinuses—still there are four frequent points of discharge: (1) Cavernous and (sphenoidal) sinus; (2) superpetrosal sinus; (3) middle of lateral sinus; (4) some sinus about the foramen magnum.

1. Some small veins from the pituitary body and other structures about the sella turcica have been described as tributary to the vene circle of Ridley. But the largest vein discharging at this point is the *Medicerebral*, a superficial vessel following the Sylvian fissure. This should be distinguished from the smaller though complementary Sylvian vein coursing at the bottom of the fissure. The medicerebral is inclined to be double, *i.e.*, there are then two parallel adjacent veins, one taking up frontal branches, the other only temporal. In this case one vein may receive some of the prebasals above described and empty into the sphenoidal or the cavernous sinus, while the other runs meso-caudad in the dura across the temporal fossa to the middle of the superpetrosal sinus. This latter is the course that the whole medicerebral vein takes in many cases, as Trolard rightly says; the dural portion may be termed the *Temporal Sinus;* by one or two lateral orifices it communicates with the medidural veins which it crosses.

2. The discharge of the subcerebral vein through the vein of Galen, as given above, holds for about one-half the cases—not always alike on the two sides. The main trunk may be diminished by the termination of some of its usual prebasal constituents in the cavernous sinus or medicerebral vein. Whether larger or smaller, the trunk as often passes to a basal sinus (superpetrosal) by turning ventrad instead of dorsad on reaching the cerebral crus.

One or more *Precerebellar Veins* from the flocculus region (*Floccular Vein*) pass to the superpetrosal sinus, with the subcerebral vein, when this terminates at the base; otherwise they seem to connect with this by veinules along the lateral surface of the cerebral crus. Among the cerebellar veins Hédon, referring to Merkel, mentions one that "comes from the flocculus and empties into the superpetrosal sinus. An important branch of this vein rises from the interior of the cerebellum in the region of the dentatum, receives also veins from the cerebellar medipeduncle, and emerges with the peduncle under the flocculus. The main trunk can acquire a very considerable size when it receives a branch of the basilar vein" (precerebellar vein, Fig. 821).

3. The *Postcerebral Veins* (Fig. 821, *M*) usually unite into one trunk just at the point where, turning caudad, they form an ampulla in the dura and enter the sinus. This is at the lateral border of the occipital lobe, opposite the exoccipital fissure. These veins come in part from the convexity, in part from the basal surface of the occipital lobe. The latter may be single or multiple; their derivative area is lateral to that of the suboccipital vein. The former is represented by one large trunk from the direction of the Sylvian fissure; it receives varying temporal branches and larger ones from the external occipital surface. The *Paracerebellar Veins* are smaller than the postcerebrals, but often empty opposite them, though, of course, subtentorial in origin. They come from the lateral portion of the cerebellum. The very inconstant *Postcerebellar Veins*, one or more in number, terminate in the lateral sinus near the torcular, or even in the tentorial.

4. The *Subcerebellar Veins* include any small vessels at the bottom of the posterior fossa discharging into the occipital sinus.

The cerebellar veins,—supra-, pre-, para-, post-, and sub-,—are but partially distinct from the cerebral veins.

Oblongata Region.—The ventro-mesal chain of myelic veins (see Fig. 821, *o*) is continued cephalad on the ventral surface of the oblongata to the furrow between this and the pons, there connecting with a fine venous network over the surface of the latter (Kadyi). This plexus in turn also connects with the veins of the cerebellum and of the base forward.

Besides irregular smaller ones, there are in particular two constant and considerable veins passing from this plexus, one on either side along the trigeminal nerve to the sinus petrosus (or cavernosus).

From the above-mentioned chain on the ventral surface of the oblongata, between the pyramids, there frequently arises a little trunk (up to 0.5 mm. or more thick) that joins one of the hypoglossal root bundles and passes out with it through the precondyloid foramen—doubtless a part of Luschka's plexus venosus hypoglossi.

The dorso-myelic chain of veins is continued cephalad over the oblongata. From a constant mesal vein here a small veinule traverses the arachnoid, covering the cisterna magna. Sometimes this adjoins the accessory nerve, and Kadyi thinks it probably empties into the sinus plexus about the foramen magnum.

General Features of the Intrinsic Veins. — *Communications.* —In this regard the pia veins must be distinguished from those of the brain substance. In contrast to the arteries, the pia veins communicate freely, not only indirectly through the sinuses, but everywhere on the surface by a network of small vessels, as well as frequently by anastomoses between larger trunks. The veins of the convexity might almost be said to radiate from the Sylvian fissure (horizontal Sylvian). At least several of the larger ones connect toward the middle of the convexity. Of these, four may be specified: (1) One of the frontal supercerebrals (fronto-dorsad); (2) the second or third from the last supercerebral (caudo-dorsad); (3) the external trunk of the postcerebral (caudo-ventrad); 4, the medicerebral (fronto-ventrad). Or any two of these trunks may communicate independently, *e.g.*, the medi- and postcerebral veins by a large anastomosis directly across the temporal lobe (intrapial, of course). There are many other connecting veins, not as markedly bridging the fissures, however. The great anastomotic vein of Trolard is No. (4) (medicerebral) when continuous with No. (2). Labbé's illustration includes also No. (3). Trolard says it "sometimes takes origin at the side of the longitudinal sinus, but oftener it forms by the union of veins anastomosing at the middle part of the convexity." He encountered it twenty-five times in thirty subjects. According to Labbé this anastomosis, instead of being with the medicerebral, may, in its absence, be with the deeper Sylvian vein. Practically these various anastomoses present a collateral path in the pia, between longitudinal, lateral, and cavernous (sphenoidal or superpetrosal) sinuses. The basal veins, excepting the perforants and the cerebellars, have ample though smaller anastomoses, including an indifferent counterpart of the circle of Willis. It is evident that the derivative area of the pia veins can never be closely defined.

The internal system must be separated into those veins uniting in the curved portion of the velar, and those tributary to the straight portion. The former, as the writer has elsewhere shown, have the following sets of

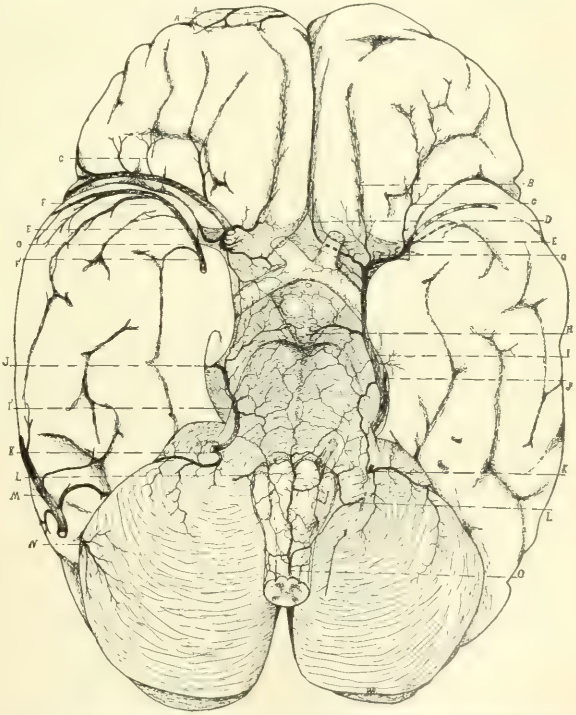

FIG. 821.—Veins of the Base (¾ natural size). The two sides represent respectively the more common arrangements of these veins. Those of the myel and oblongata are largely after Kadyi. A, A, Supracerebrals; B, ramus to olfactory bulb; C, C, subfrontals; D, precerebral; E, E, Sylvian or insular; F, medicerebral (to cavernous sinus); F′, postmedicerebral (per temporal sinus to superpetrosal); G, G, preperforantes; H, postperforantes; I, subcerebral (to Galen's vein); I′, subcerebral (when emptying at base); J, J, subcornuals; K, K, precerebellars and flocculars; L, L, hypoglossals (to precondyloid emissary); M, postcerebral (to lateral sinus); N, paracerebellar (to lateral sinus); O, ventromyelic (anterior spinal).

anastomoses: (1) Between the callosal vein—including practically the rare interhemispheric vein—and the median branches of the supercerebrals, across the callosal fissure; (2) between the suboccipital vein and the basal branches of the postcerebral; (3) between the supercerebellar and other cerebellar veins; (4) between the subcerebral vein—when, as in about one-half the cases, this discharges into the velar—and the many veins adjacent to its derivative area. These communications are all in the pia; from clinical cases we know that these may suffice to compensate fairly when *only* the tentorial sinus and the short common vein of Galen are closed. They do not suffice, however, when there is any impediment to this collateral discharge, and possibly not when the subcerebral vein ends elsewhere. Of the veins passing to the portio recta of the velar vein, only one, the medicornual, has superficial anastomoses. As this is a long, tortuous vessel, and connects with the subcornual only by small and questionable anastomoses, it is of itself entirely unable to compensate when the portio curvata becomes occluded. We have, remaining, the various cœlian veins coming directly from the brain substance, to which the postcornual may also be added. Neither between these nor between their subdivisions short of the ultimate capillaries did the writer succeed in finding any anastomoses. The same holds true for the perforating veins of the base. There still might be intrasubstantial connections between these vessels and the cortical veinules. However, the apparently positive results of injections by Duret, and especially by Labbé, are all explicable by the surface anastomoses above described. There may be such occasional but inadequate connections paralleled by the rare ones between the otherwise terminal perforating and cœlian arterioles. Hédon (1888) says that a few do exist. Clinical evidence also goes to show that the veins emanating from the cœlial walls are all essentially terminal vessels, and that closure of the velar vein—unless just at its mouth—cannot be compensated.

Cortical Veinules.—Duret found only six or eight in the section of a medium-sized convolution, one or two emanating perpendicularly at the dorsum of the gyrus, and from four to six by the sides. However, they had a diameter triple that of the arterioles. They start principally from the capillary transition plexus—between gray and white—and from the deeper albalis.

Developmental.—From various peculiarities in the vascular supply of the human brain, more especially the caudad displacement peripherally of the postsupracerebral veins, the writer has adduced evidence favorable in a general way to Hill's theory of a developmental rotation of the brain, and showing further that in any such rotation the brain and pia have glided caudad under the dura and brain case.

Here may be added a casual observation of a persistent fetal form, made at the autopsy of a child of twenty-two months, dead of tubercular meningitis. The large left medicerebral vein took the temporal course in a deep groove (per temporal sinus, intradural), and passed out at the foramen jugulare spurium instead of passing to the suprapetrosal sinus, first, however, connecting with a much smaller prepetrosal sinus. No such appearance on the right.

General Relations of the Veins and Arteries.—In the pia, over the convexity and on the median surface, the arteries lie beneath the veins (Labbé), as generally in the body elsewhere. But over the insula, and evidently in the sulci generally, the writer has observed the reverse; while of the finer pial arborizations Labbé asserts that the venous lie beneath the arterial. Though the larger veins often jump across from one gyrus to the next, the arteries go down with the pia more or less deeply into the fissures, to come up near or distant over the next gyrus.

Only by a forced comparison can any of these veins be said to accompany the arteries. By contrast, the dural vessels conform in their general bearing to those elsewhere; they have abundant collateral anastomoses, most of the arterial branches are accompanied by two veins, etc.

Dwight quotes the suggestion that, as the blood in the internal jugular and carotid flows in opposite directions, the arterial pulsations might interfere with the venous discharge, if both lay in a common canal. Trolard drew a strong analogy between the vertebral artery, surrounded by the vertebral vein and plexus, and the carotid through the cavernous sinus. "The supply arteries of the encephalon bathe (?) in venous blood; the carotids from the moment they enter the carotid canal; the vertebrals from the moment they penetrate the vertebral canal." This point has been elaborated by Rüdinger (*vide* abstract in Boston *Medical and Surgical Journal*, 1888, ii., 323). He shows that by this cushioning the pulsatory movements of the arteries are not abolished as they would be if they filled the bony canals. The diameter of the carotid canal he gives as 5–7 mm.; that of the artery, 3–4.3 mm. In the cavernous sinus the artery, though situated at one side of the cavity, is not in contact with either the bone or the dura.

The various retarding bends and angles in both classes of vessels can only be referred to. They affect very unequally the circulation in the different parts. The existence in the pia of vessels larger than capillaries, connecting the arteries with the veins, has been many times asserted and denied—the last investigator, Labbé, contriving to do both. This point still awaits final settlement.

III. The Dural Sinuses.—The encranial sinuses are all intradural, and all except the tentorial (with the falcial) lie against the cranial wall. They do not collapse on being slit open, nor do they admit of much distention—the falcial and the parasinual spaces excepted. They are lined by a continuation of the inner membrane of the jugular. Allen counts 16 sinuses—10 paired (symmetrical), and 6 unpaired (azygous). But their number depends so much on the way they are divided as to cause the remark that the easiest piece of anatomical work was to describe a new sinus.

They have been variously classified: (*a*) In two reciprocally perpendicular planes, the vertical plane including the longitudinal and tentorial (plus falcial), the horizontal including the remaining; or (*b*) in three horizontal planes; or (*c*) as connecting at three points, viz., the torcular and the two cavernous sinuses (to which Trolard sought to add a precondyloid confluens); or (*d*) according to the area drained.

The Longitudinal Sinus.—This, the longest sinus, runs parallel to the sagittal suture, slightly grooving the bone in a curved line from near the crista galli to the internal occipital protuberance. It lies between the folds of the falx, as they diverge to continue as the parietal dura. Its section presents a rounded triangle, increasing in size from the accession of large veins. Its lumen toward the bottom is crossed by numerous irregular strands (trabeculæ, chordæ Willisii). The openings from the supercerebral veins are usually larger than those from the parasinual spaces (and dural veins). The sini subalterni of Malacarne are often seen in the falx just beneath the sinus, and present more or less developed parallel narrow passages freely connecting with the main vessel. At the torcular this sinus more often turns into the right lateral. Rarely it, or its tributaries, drops down through the falx to the falcial sinus, or just before the torcular to the tentorial, or even divides, following the lambda sutures to each lateral sinus. The whole longitudinal sinus may be occluded without causing disastrous results.

Falcial Sinus.—This may run along about two-thirds of the free border of the falx or near the border, and then represents the continuation of the tentorial sinus. It is rather a large dural vein than a sinus. At its commencement the occasional interhemispheric veins empty. Its only lateral tributaries are usually small dural veinules, though part of the supercerebral veins or of the longitudinal sinus have in rare instances been seen to turn this way. On the contrary, Knott once saw the falcial pass to the longitudinal, and some connection between the two is not uncommon.

But, as stated by Luschka, this sinus is very variable in size and occurrence. In a series of adult subjects the writer found that its average occurrence was only one in six; in the fœtus it was never present. Trolard's attempt at presenting this as an important anastomosis between the dorsal and internal systems, or as a safety diverticle of the latter, was quite overdrawn.

Tentorial Sinus.—This lies at the junction of the falx and tentorium (Figs. 819 and 820, *a*). It extends in full size from the torcular to the intersection of the free falcial and tentorial borders opposite the point where it receives its main tributary, the vein of Galen. Its section is a triangle with narrow base resting on the tentorium. Laterally it takes up small dural radicles, and often a supercerebellar vein. It is straight, lies in the median line, and is directed caudad. "It opens into the lateral sinus by an oval mouth formed by strong pillars of fibres."

Torticular.—A *confluens sinuum* in the sense of the old writers does not exist. "The right lateral sinus for the most part begins higher than the left, and may be considered as the continuation of the longitudinal. In some subjects the right or left lateral sinus begins from the longitudinal one, while that of the other side is continuous from the tentorial; and then the lateral sinuses are separated at their origin by a membranous isthmus" (Charles Bell, 1827). Rüdinger speaks of a "valvular arrangement" separating the two currents. In 26 out of Knott's 44 cases, the tentorial opened into the left lateral sinus, in 6 into the right, in 12 mesially. The statistics given below, on the larger jugular canal, bear on this question. This peculiarity of the paths at the torcular tends to prevent a reflux of blood from one into the other, or any interference of the currents.

However, in a considerable minority of cases the currents must intermingle. From the arrangements of the sinuses at the torcular, thrombosis of the longitudinal and right lateral is more often associated than of the longitudinal and left. A comparison of the few casual cases at hand shows 6 of the former to 2 (or possibly 3) of the latter. Of course, much more frequently—in 12—all three sinuses were involved.

Lateral Sinus.—This runs from the torcular, at first in the attached tentorial border, then curves (*flexura sigmoidea*) to follow the groove in the mastoid and gains the jugular canal. It has been seen to take a more basal course, running first in the cerebellar falx, then beside the foramen magnum to its usual exit. From the extensive investigations of Hartmann, Rüdinger, Bezold, and Politzer, it appears that frequently the sigmoid portion approaches within a few millimetres of the posterior wall of the auditory meatus. The one into which the longitudinal sinus turns, usually the right, is double the size of the other, and also a trifle longer. Rarely, one lateral is minimal in size or even absent. It receives laterally the postcerebral and paracerebellar veins and superpetrosal sinus, and gives off two inconstant emissaries.

Körner (1889) has shown that intracranial disease from caries of the petrous is more frequent on the right, and from a study of 449 skulls he attributes this to the fact that the lateral sinus at its sigmoid flexure enters deeper into the mastoid and the petrous pyramid on the right than on the left, and thus on the right approaches nearer the primary focus of disease. In 22 cases on the right and 8 on the left, there were gaps in the bony partition. He also holds that in the brachycephali the sigmoid excavation goes lower and deeper than in the dolichocephali, and that hence in the former such encranial sequelæ follow more readily; but this has been disputed by Schülzke.

Birmingham, of Dublin (*Brit. Med. Journ.*, 1890, ii., 683), from an examination of 100 recent dry specimens, points out that the relations of the lateral sinus to the surface are extremely uncertain, owing both to variations in the sinus curves and to irregularities in the bones. It begins opposite the external occipital protuberance in 50 per cent.; lower (by never more than one-half inch) in 33 per cent.; and higher in 17 per cent. It does not run forward horizontally, but is distinctly arched. The bend of the sinus where it turns down at the asterion may vary, within wide limits, from a gentle to a very sharp curve. It then runs down in front of the postmastoid margin, about one-half inch behind the meatus, and turns into the jugular foramen about one-quarter inch below the level of the meatus floor. Occasionally the sinus is only one-twelfth of an inch from the surface.

Cavernous Sinus (Plate XVIII., Fig. 1), distinguished by its irregular outline and cellular or reticulated appearance from intercrossing fibrous bands. It represents a colossal perivascular structure about the carotid, in a way similar to that established by Braune and his school for certain lymphatics accompanying veins. The late von Langer, in one of his last publications, based on corrosion and other preparations from infantile subjects, showed that the cavernous sinus is originally a plexiform network of veins, which, by fusion of its channels, takes on its later characteristics. The wall resorption goes on to old age, when villous offshoots of the remaining trabeculæ are often seen to project into its cavity. It is traversed by the carotid (cavernous portion). All the orbital nerves except the optic pass near or through its outer wall. Besides veins and emissaries, it is the communicating centre for all the prebasal sinuses. Frontad it tapers to the ophthalmic vein—the swollen end of which has been dubbed *Sinus Ophthalmicus*.

Laterally, the cavernous receives the *Sphenoidal Sinus*. This runs out along the dependent side of the lesser sphenoidal wing. Knott notes great variability in its size, though never complete absence, a small vein at least being found. Peripherally it receives or connects with a medidural vein, and also a diploic canal, and may take up the medicerebral and connect with ophthalmodural veins.

The *Subsphenoidal Sinus*, on the great wing of the bone, was found by Knott fourteen times on the right and nine on the left side.

Mesad, the cavernosi connect by the two *Transverse Sinuses*—which alone deserve to be called transverse. These follow the walls of the sella turcica, curve slightly to enclose the pituitary body, and complete the so-called vene-circle of Ridley (Plate XVIII., Fig. 1).

Sinus Præpetrosus (jugularis spurius of Luschka, petroso-squamosus of Hyrtl, petrosus anterior of Bell). This occasional sinus, at the bottom of the temporal fossa, describes a curve along the petro-squamous suture, from the spinous foramen—connecting with the medidural vein and also with the cavernous sinus—to either (or both) the emissarium temporale or the petrous portion of the lateral sinus (often by perforating the prominent petrous ridge). Its physiological interest arises from the prominent part which it plays in the fœtus. Zuckerkandl (1873) found this sinus 22 times in 280 skulls. Knott, 4 times in 44, found what appears to have been a continuation of this sinus to the sphenoidal; in 7 of 44 subjects he found the prepetrosal on both sides, in 19 on one side only.

Caudad, the cavernous empties into the oblique super- and sub-petrosal sinuses, but principally the former. The *Superpetrosal Sinus* starts from the cavernous, runs in the prolonged attached border of the tentorium along the dorsal ridge of the petrous bone, and enters the lateral sinus against the current at the beginning of its sigmoid flexure. It alone offers a direct encranial connection between the prebasal and lateral sinuses. The temporal sinus (medicerebral or anastomotic vein) and the subcerebral vein discharge into this in nearly one-half the cases, the precerebellar vein more constantly. As a consequence, its size varies considerably, though it is usually small. The vestibular and even tympanic veins of the ear pass to the superpetrosal sinus, either directly or by a dural vein. In his forty-four subjects, Knott notes its absence twice on the right and once on the left.

The shorter *Subpetrosal Sinus* runs in the petro-occipital groove, from the cavernous sinus to the subpetrosal vein, which, by bending before its discharge into the jugular vein, secures an unimpeded outlet for this sinus (for connections, *vide infra*, Vena Subpetrosa).

Occipito-Basilar Plexus.—In the occipital fossa are several sinus canals that vary much in size and distribution. The *Occipital Sinus,* usually bilateral, runs along the cerebellar falx and connects with the lateral sinuses by small mouths beside the torcular. Pre-, trans-, and postoccipitals have been made out. The so-called circular sinus of the foramen magnum is more often incomplete dorsad of the hole. The basilar sinuses over the likenamed process connect with the preceding and with the prebasal sinuses. Langer has shown that, like the cavernous sinus, all of these are the persistent channels of what originally, in the fœtus, was a vein plexus; and he has also corroborated Virchow's description of their enlargement in the aged.

Parasinual Spaces.—These areolar venous pockets or derivative reservoirs (lacunæ, *recessus lateralis*), though described with increasing definiteness by a long series of observers, find but little mention in the text-books. Their principal development is opposite the middle of the longitudinal sinus (bilateral). As numerous minute spaces they further occur along nearly the whole length of the said sinus, and also (Langer) beneath it in the falx, beside the lateral sinuses, on both sides of the tentorial sinus, and it is said even about the cavernosi. The dilated intradural termination of the postcerebral and paracerebellar veins has also been thus classed. They all occupy the attenuated space between the dural layers lateral to the sinuses, and hence are very shallow and of irregular outline. They have a lining membrane, also many intercrossing fibrous filaments, and are injectable from or with the sinuses. In position and characteristics they are intermediary between dural veins and sinuses. Where present they receive most if not all the dural veins. The larger spaces are traversed by incoming pia veins with which they connect by one or more openings. They increase in size as life advances, and then have intimate relations with the Pacchionian granulations—so much so that they have even been termed Pacchionian blood cavities. The circulation in their interior is not believed to be very active and the spaces have repeatedly been found thrombosed.

On opening a sinus or the jugular canal blood usually flows out in a more or less pulsatory stream showing that the ruling interior pressure is positive. In the cases of operative perforation of a lateral sinus (Jacoby, Knapp, Benton, Guye, Owen, Reeve, von Baracz, and others, usually ending in recovery) there is no record of air being aspirated. But in one case of opening of the longitudinal (Genzmer, 1877) so much air was aspirated as to prove quickly fatal, and Francois-Franck (1881) has endeavored by experiments to show that aspiration can be communicated through the vertebral veins to the diploic canals of the occiput.

Occlusion.—Blocking of any single sinus is not necessarily dangerous, though occlusion of a cavernous or the tentorial is always a serious matter.

By experimental blocking of the dural sinuses in the dog, Ferrari (1888) has shown that a large part of the whole sinus system, *e.g.*, all the sinuses of the calvarium, may be rendered impermeable without injury to the functions of the brain. However, occlusion of the collective blood efferents from the skull is of course quickly fatal, being usually preceded by an epileptic attack. But all this and more had been already determined by clinical experience in man.

IV. VENOUS OPENINGS THROUGH THE SKULL (EMISSARIA, ETC.).—From their number and pathological importance, and for clearness of description, these passages ought to constitute a separate class. Each of the cranial bones (except the ethmoid) has a foramen permitting direct communication between the dural sinuses and veins and the exterior veins; still these are of very unequal size, and in part disappear in the adult. There is but little topographical correspondence between the position of these exits and the area drained through them; nor is the area in any case closely definable. They may all act as efferent vessels, although the ophthalmic veins are usually afferent—partially so, says Sesemann, 1869; largely so, Gurwitsch, 1883, and Merkel—and certain of the others may conduct either way according to circumstances. Only Nos. 2, 6, 7, and 8 are superficial, while 7, 8, 11, and perhaps 4, belong rather to the dural and diploic system. Nearly all the blood normally passes out through the two postlacerated foramina with their four canals. But any one of the exits and, so far as known, any two—or, in case of the smaller emissaria, several—may be permanently closed without causing serious harm. Both internal jugulars have been tied in the same subject (Pilger, 1880) without other evil consequences than a temporary headache.

1. *Jugular Canal.*—In the lateral part of the postlacerated foramen. This, by far the largest of all the exits, leads from the sigmoid flexure of the lateral sinus to the bulb or gulf of the internal jugular vein. Its path through the foramen is often more or less separated from the passing nerves, etc., by a bony septum, thus forming a true jugular foramen. Rarely it is very small on one side, or even absent (four or five known cases).

By adding the series of 159 skulls examined by Dwight to the 100 by Rüdinger, we have 259. In 173 of these the right jugular foramen was larger than the left (*i.e.*, about two-thirds), in 65 the reverse (one-quarter), and in 21 the two were equal (one-twelfth). This harmonizes with what was said above (*sub* Torcular).

2. *Emissarium Mastoideum,* of most importance in fetal life. It arises directly from the lateral sinus, and empties usually into the occipital vein (extracranial), sometimes into the postauricular, or even directly into the external jugular. In the 16 perfect skulls examined by Green (*American Journal of Otology,* vol. iii.), it was absent on both sides in 1, and on one side in 1. It was always just behind the posterior limit of the mastoid process. The external opening was opposite the meatus (at about the middle of the perpendicular height of the mastoid) in 20, above this in 2, below in 6, and directly on the base of the skull in 1. Its diameter measured 5 mm. in 1, 4 mm. in 4, 3 mm. in 10, 2 mm. in 10, and 0.5 mm. in 4.

3. *Emissarium Postcondyloideum* (postjugular vein), passing from the lateral sinus near its termination to the upper cervical or vertebral veins. In 44 skulls, Knott found this on both sides in only 13, on the right in 21, and on the left in 10. In Dwight's series of 142 skulls, with unequal jugular foramina, the postcondyloid foramen was larger on the same side as the larger jugular in 53, on the other side in 37, and equal or absent in 52 (this foramen being wholly for the transit of the emissary).

4. *Emissarium Præcondyloideum,* connecting with the occipital sinus or its basal prolongation, taking up a diploic vein, and passing in part to the prepetrosal vein, in part to the plexus about the vertebral. As plexus venosus hypoglossi, Luschka described a cluster of veins about the hypoglossal bundles as they unite in the inner portion of the foramen, from which two veins passed down the canal. Trolard says that externally the precondyloid foramen presents a deep cavity in which is lodged a true venous confluens. Ventrad its wall is hidden by the external part of the atlo-occipital ligament. He says that this confluens receives five veins: (1) Ventrad and mesad, the medilacerate; (2) latero-ventrad, a connection with the subpetrosal vein; (3) dorsad, a precondyloid vein; (4) latero-dorsad, an inconstant vertebral vein (passing between atlas and occiput, behind the internal jugular, sometimes in a bony canal); (5) a little vein on the preatlo-occipital ligament, communicating across with the intraspinal sinuses.

Dwight, in the same series of 142 skulls, found the precondyloid foramen larger on the same side as the jugular in 16, on the other side in 11, the two sides equal in 115. "There does not appear to be any definite relation between their size and that of the postcondyloids."

5. Small uncertain veins through the *foramen magnum* or beside the vertebral arteries, connecting some marginal sinus or vein with the vertebral and spinal vessels. The fine veins in the spinal cord also connect with intrasubstantial ones above.

EXPLANATION OF
PLATE XVIII.

EXPLANATION OF PLATE XVIII.

FIG. 1.—Sinus Cavernosi et Intercavernosi—Sinus Circularis of Ridley.

Inferior aspect of a corrosion preparation from a child, with afferents and efferents (somewhat enlarged, and also arbitrary as to execution of smaller vessels). From Langer's "Der Sinus cavernosus der harten Hirnhaut," *Sitzbr. d. k. Akad.*, 1885, Vienna (Fig. 5).

V.o., Vena ophthalmica superior et inferior.
S.i.c., Sinus intercavernosi.
E, Emissary veins passing through the oval foramen to the pterygoid plexus.
S.p.i., Sinus petrosus inferior.
L, Space for the dorsum ephippii.

FIG. 2.—Fine anastomotic network between three arterial twigs in the pia of the parietal region (Lucas, Paris Thesis, 1879.)

Fig. 3.—Lobule of a choroidal villus; one portion bare of epithelium. Sinuous vascular loop. Enlargement, 500 diameters. (From Luschka.)

a, Portion covered by epithelium.
b, Fibrillary connective tissue.
c, Structureless connecting substance extending well beyond the capillaries.

FIG. 4.—Very perfectly injected vessels of a choroidal villus. Two hilus vessels, a vein, and an artery. Loops, vascular nets, etc. Enlargement, 50 diameters. (From Luschka's "Die Adergeflechte des menschlichen Gehirns," 1855, Taf. ii., Fig. 2.)

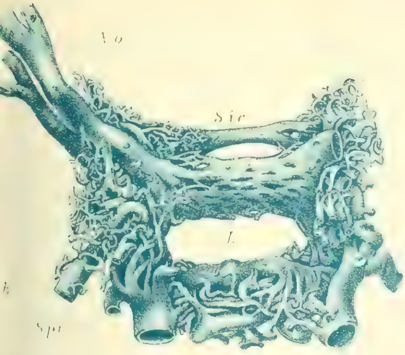

Fig 1.

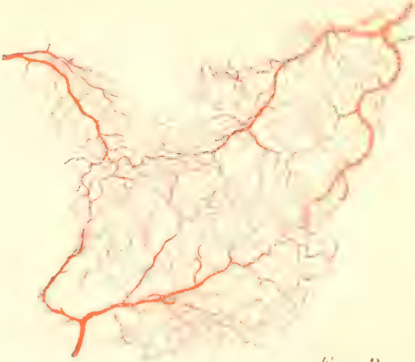

Fig 2.

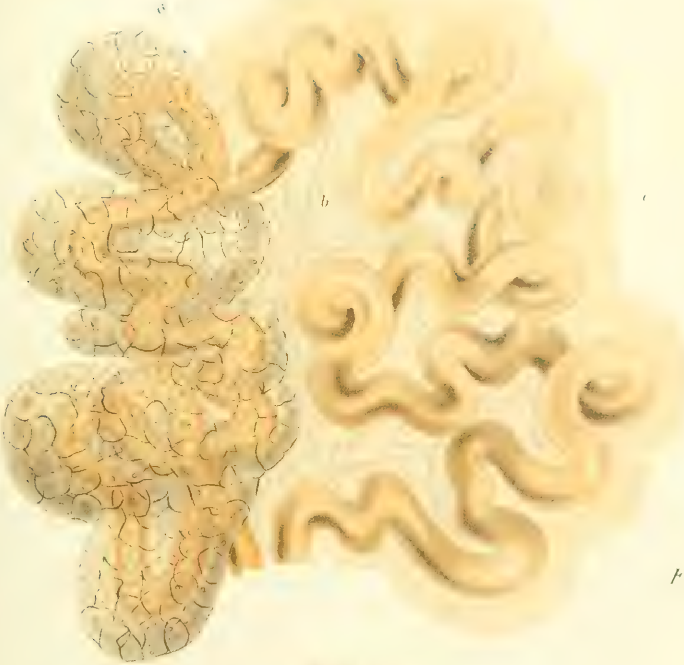

Fig 3.

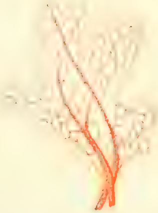

Fig 4.

Brain-Vessels.(Vide Explanation at End of Article).

6. *Emissarium Occipitale,* a small mesal conduit from the torcular through the occipital protuberance to the external veins of the occiput. It is often, but not always sinuous, and takes up an azygoid diploic trunk. Knott found it as a small but traceable vein in 6 of his 44 cases. In most of the others there was a small vein piercing one of the bone plates and anastomosing with the diploë veins.

7. *Emissarium Parietale.*—In 100 skulls Gruber found the parietal foramen on both sides in 29, on the right in 19, on the left in 12; average distance from angle of occipital squama, 3–5 cm.; distance from sagittal suture, 2–17 mm. Their size varies ordinarily from ⅛ to 1 mm. They do not terminate internally directly in the long sinus, but in the parasinual spaces or dural veins.

8. *Diploic Connections.*—Innumerable small openings through the inner plate of the skull connect the dural veins and spaces with the diploë canals. These are largest and most numerous along the longitudinal sinus (corrosion preparation).

9. *Orbital Connections.*—(*a*) The ophthalmic vein is, next to the jugular, the largest and most constant of all the passages. It empties largely into the cavernous sinus (through the orbital fissure, where it bears a constant constriction), but has free anastomosis with the prefacial vein at the inner canthus. Allen says that formerly the trunk of the facial was opened at this point to relieve cerebral congestion. (*b*) The central retinal vein has full anastomoses with the ophthalmic, but goes as a rule to the cavernous sinus, or frequently to a fine venous plexus around the optic nerve, and then by several veinules in part to the subophthalmic vein, in part to the said sinus. (*c*) The smaller subophthalmic vein or veins connect doubly with the larger into which, or oftener into the sinus cavernosus, they discharge (always afferent, say Sesemann and H. Meyer). Peripherally, they anastomose with facial and even pterygoid veins. (*d*) The ophthalmo-dural vein of Hyrtl (1859) is practically included under the more or less constant connection of the medicerebral vein and the sphenoid sinus. Occasionally this sinus or vein has a small anastomosis, through the lateral part of the orbital foramen, with the ophthalmic or other orbital vein. Evidently, the vena aberrans of Verga (1856) should be classed here. As a passage from the ophthalmic vein or cavernous sinus to the lateral sinus, Knott mentions one case (on right); or between ophthalmic vein and superpetrosal sinus, three instances (on left).

10. *The Emissary of the Foramen Rotundum* from the cavernous sinus, and accompanying the superior maxillary nerve as described by Nuhn, was twice seen by Knott (on right).

11. The medidural vein discharges largely through the *oval,* or *spinous, foramen.* Nuhn described a pair of veins which, after traversing the oval foramen, formed a plexus about the inferior maxillary nerve and terminated in the infratemporal veins. Knott found these veins on both sides in 18; two veins on right and one on left in 6, the reverse in 4; a single vein on each side in 11; no vein on one side in 5. Luschka and Trolard describe a vein, from the cavernous sinus, that receives dural veins from the anterior petrous surface and departs through the oval foramen; in this case the medidural emerges through the spinous foramen.

12. *Plexus s. Sinus Caroticus.*—Bell (1827) mentions a *vena sodalis arteriæ carotidis,* as an emissary from a petrous sinus, descending through the carotid canal. Rektorzik (1858) seems to have rediscovered this. A prolongation of the cavernous sinus into the carotid canal constitutes the sinus caroticus. This breaks up into a plexus of small veins about the artery, converging to one or more small trunks below, that may pass to the internal jugular. It may connect with 11 and 13. Knott was always able to find this communication, though the vessels varied much in size and number.

13. *Vena Medilacerata.*—Englisch is credited with having described (1863) a constant communication, outside the skull, between the cavernous sinus and the subpetrosal vein. As *inferior petro-occipital sinus,* Trolard independently described the same. "On the exterior base of the cranium a small vein occupies a groove extending between the two lacerated foramina. Its direction is latero-caudad. It inosculates with cavernous sinus or carotid plexus, and with the precondyloid confluens" (*vide supra, sub* 4). Knott found this in 14 out of 33 cases.

14. *Vena Subpetrosa,* from the subpetrosal sinus, through the premedian portion of the foramen postlacerum, to the jugular vein. Here it is separated—not rarely by bony lamina, thus forming the foramen anomalum of Gruber, 1869—by three nerve trunks from the jugular canal. From numerous investigations Gruber found that only rarely did this vein pass quite through the foramen before entering the jugular, and that then it first connected with the termination of the lateral sinus. However, in 8 out of 22 times Knott found that the vena subpetrosa ended at about the level of the lower margin of the jugular foramen, in 9 a little above, and in 5 a little below. It connects also with the precondyloid vein or confluens, and commonly receives the internal auditory veins.

To these may be added the following, of rare occurrence in the adult·

15. *Emissarium Temporale* (foramen jugulare spurium). This is held to be a relic of the primary jugular vein. When present, it proceeds from the prepetrosal sinus, perforates the temporal bone beneath the root of the zygomatic arch, emerges just behind the glenoid fossa at the edge of the porus acusticus externus, and ends in the external jugular system.

16. *Foramen Cæcum,* in fetal life a communication between the longitudinal sinus and the veins of the frontal sinus, ethmoid bone, and nose. Rarely, if ever, observed in the adult.

17. The very rare pathological venous blood tumors of the cranium (*vide* Mastin, *Journal of the American Medical Association,* 1886), arterio-venous aneurisms of the scalp, etc., occasionally communicate on the one hand with external veins of the head, on the other through openings in the bone usually with the long sinus.

18. Possibly a couple should be added from Hédon. Small rami accompany the olfactory bundles through the cribriform plate of the ethmoid, of course connecting above with the vein of the olfactory bulb. "A vein leaves the aqueduct of Fallopius by the stylomastoid foramen to anastomose with the external jugular or post-auricular (Sperino). It joins, according to Blandin, a small dural ramus traversing the hiatus of Fallopius."

LYMPHATIC SYSTEM IN THE BRAIN.—There are no lymphatic glands in the cranial cavity; nor does the brain possess a system of independent lymphatics. Within the brain substance all the larger lymph passages accompany the blood-vessels as cylindrical enveloping spaces. These are at least twofold: (*a*) *Adventitial* spaces between media and adventitia, which latter are not closely bound together in the vessels of the central nervous system as in the remainder of the body; (*b*) *perivascular* spaces of His and Robin, connecting with the subpial or so-called epicerebral space. Their existence in normal tissues has been repeatedly disputed, and unquestionably their size is artificially much increased by the usual methods of preparation. The latest investigators, Rossbach and Sehrwald, assert very positively the real existence of these spaces. They worked by Golgi's method, claiming that this marks the lymph, and thus the lymph spaces, rather than the ganglion cell and its processes.

The beginning of the lymph passages is to be sought in the very narrow spaces surrounding the ganglion cells —*pericellular spaces* (Obersteiner). To each of these latter spaces run, according to Rossbach and Sehrwald, many fine canals (rootlets), often coming a long distance through the albalis, and starting about vessels and from glial lymph spaces. These surround the protoplasmic cell processes. The efferents from these cell spaces pass along the apex process, branch, and empty into perivascular and superficial glial spaces, or directly into the epicerebral space. The lymph system of each ganglion cell has no direct anastomoses with that about any other such cell. They also describe a lymphatic plexus about the glia cells (*periglial space*), especially in the external cortical layer, and in the first subcortical albalis. These are often intermediary between the pericellular spaces and the perivascular spaces, into which latter and the epicerebral space they empty.

The results of Rossbach and Sehrwald, regarding lymphatics in the brain substance, are evidently discredited by Frommann (*Centbl. f. med. Wiss.*, 1888, pp. 881, 882). As regards the hypophysis, Pisenti and Viola (*ibid.*, 1890, pp. 451, 452) believe that certain structures observed by them represent lymph spaces. A cortical lymph-connective system has been studied by Bevan Lewis.

The lymphatics of the choroid plexus in the paracœle unite (Arnold) to one trunk following Galen's vein. In the ependyma lymphatic networks have occasionally been observed.

The lymph passages collect in the pia to larger trunks, follow the course of the veins, and pass out, in part through the jugular foramen to superjugular glands, in part through the carotid canal to the deep cervical glands, in part beside the vertebral vessels to the infrajugular glands.

Little evidence of lymphatics in the myel is found by Kadyi. The perivascular spaces of His occur, but are likely of artificial origin. From the results of one injection he figures a network of voluminous canals running longitudinally beside the central canal, and that possibly represent a lymphatic system.

Serous Cavities, Cerebro-Spinal Fluid, etc.—Between dura and arachnoidea is the *subdural space.* In the normal condition this contains only a capillary layer of fluid. The dura has a system of lymphatics accompanying the blood capillaries, within their adventitia. Besides, in the endothelium of the dura independent lymphatic plexi and stomata have been described, presenting a communication with the subdural space, and conducting off the subdural fluid. Through the oval and spinous foramina pass (Arnold) lymphatics to the deep facial glands, probably coming from the dura.

The interstices of the pia, *i.e.*, the somewhat broken room between arachnoid and pia proper, constitute the subarachnoidal space (*cavum subarachnoidale*). This is the retainer of the cerebro-spinal (cephalo-rachidian) fluid. Although this fluid can pass back and forth between the corresponding cephalic and spinal spaces, it is no longer held that there is a continuous ebb and flow from one to the other at each respiratory movement and even pulsation. This space is exceedingly attenuated wherever the brain lies close to the skull, as over the convexity. At other points it forms lacuna-like pockets, termed by Key and Retzius cisternæ. Among these may be mentioned: *Cisterna magna* (*cerebello-oblongata*), where the arachnoid spreads across from the caudad border of the cerebellum to the oblongata; *cisternæ frontis* (*laterales et media*); *cisterna Sylvii;* and over the optic lobes the *cisterna ambiens.* The cœles connect with these cavities (the cœlian fluid comes from the choroid plexuses—*vide* Plate XVIII., Figs. 3 and 4); the metepicœle with the cisterna magna through the foramen Magendii and the aperturæ laterales; the paracœle with the diacœle per the foramen of Munro; and the diacœle with the metepicœle through the aqueduct. There is no canalis Bichati, formerly supposed to connect the paracœle with the subdural space. Hence, while the cœlian and subarachnoid cavities are united, neither has any direct connection with the subdural space. An indirect connection may be offered by the nasal lymph net, as this may be injected from the subdural as well as subarachnoidal space, by way of perineural lymph passages about outgoing nerves. Another assumed indirect connection is by Pacchionian bodies and the sinuses. The experiments of Key and Retzius, confirmed by Kollmann (1880), seemed to show that the perforations of the dura—opposite venous spaces—by these bodies furnish one of the principal discharge paths for both subarachnoidal and subdural spaces. Probably, however, their injections produced artificial openings, not existing *intra vitam.* Certainly they do not usually attain any development until long after youth has passed. Further reasons in opposition are given by Adamkiewicz in his polemic (Eulenburg's "Real-Encyclopädie," 1886, art. "Gehirndruck") against Bergmann's theory of brain compression, and in favor of his own somewhat novel views. Material injected into the subarachnoidal space in animals traverses the supercervical and submaxillary glands. In man it can pass out in the optic sheath to the bulb, in the sheath of the facial and the acoustic as far as the internal auditory meatus—whence fracture of the petrous with tearing of the nerve sheath leads to oozing out of cerebro-spinal fluid—and finally to the lymphatics in the nasal mucous membrane, the supposed path of meningeal infection from nasal sources.

The writer has recently shown that during the whole of fetal life in the human subject, there exist efferent passages for the cerebro-spinal fluid along the larger nerve trunks from the spinal cord, notably those from the lumbar enlargement. After birth, however, these promptly close up. In the lower animals they are more persistent.

The subarachnoidal cisternæ protect the large basal vessels from compression, and in like manner the pericellular spaces shield the enclosed cell and its process from shock and pressure. Further, the perivascular channels protect the brain substance (His) in a more general way.

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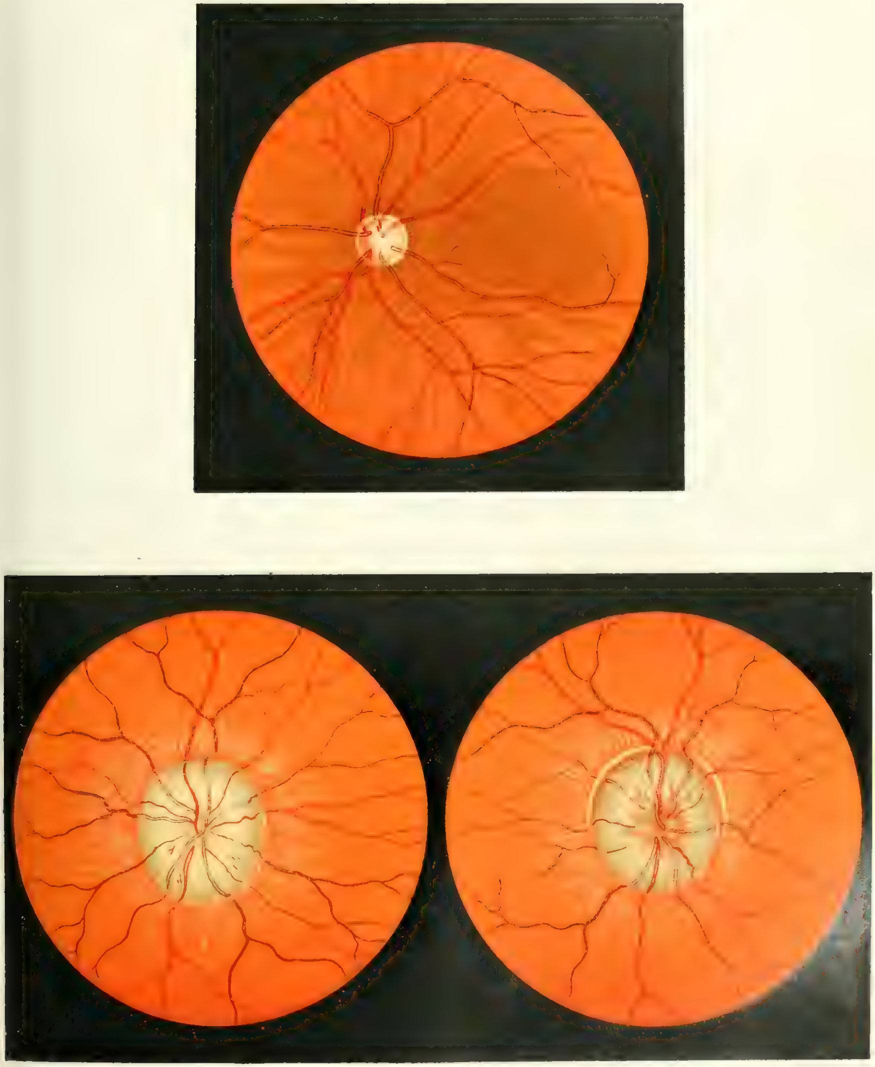

Representation (in the two lower pictures) of the condition known as "Choked Disk," as seen with the ophthalmoscope. For purposes of comparison, the appearance of the normal fundus oculi is shown in the upper picture.—*(From Haab—Atlas of Ophthalmoscopy.)*

Lymphatics.

Many articles by Arnold (1838), Hyrtl (1860), His (1865), Robin, Schwalbe, Obersteiner (1870), Riedel, Arndt, Krause, etc.
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BRAIN, COMPRESSION OF.—Notwithstanding the unhappy use of a word that does not describe the subtile condition it is meant to express, the term compression is a convenient one that seems justified by the necessities of analysis and study. It is generally used in a pathological sense to describe a complexity of symptoms arising from a particular state of the brain characterized mainly by disorder of the circulation within the cranium, and manifested by more or less derangement of the three great faculties of the nervous system.

As a principle used to account for the phenomena of brain disease, and as a complication that is often present after various lesions of the brain and its membranes, the special and differential diagnosis of compression is of grave importance, and includes a wide range of cerebral pathology. The prevailing opinions of writers on this subject are somewhat misleading, since compression, in its true sense of occupation of less space, is a condition of the brain which in most cases seems to be assumed rather than demonstrated to exist, and it is rare to find a case of compression in which there are not present the symptoms both of concussion and laceration of the brain.

Etiology.—The squeezing of its constituent parts or the diminution of volume that is supposed to interfere with the functions of the brain may be effected by pressure from without the encephalon, or by tension within its proper substance. The condition arises from a great variety of causes, most common of which are cerebral tumor, hemorrhage, and inflammatory foci. Hypertrophy of the brain, simple congestion, hydrocephalus, and effusion from various causes may result in compression. The effusion may take place quickly or slowly. Some experiments, however, point to the fact that the symptoms of compression are not to be attributed to augmentation of tension of the cephalo-rachidian liquid.

Other causes are foreign bodies, loose splinters, or larger portions of depressed bone, and, in fact, any injury of the head, whether simple contusion, scalp wound, or fracture of the skull. Whatever be the cause of compression, it should be borne in mind that the most characteristic symptoms are brought about by *sudden* action, for compression established slowly upon the brains of animals by the injection of a liquid causes no appreciable symptom, unless the quantity injected be unusually large; and it should be further remembered that, in the human subject, appreciable symptoms of compression are not always induced by such causes as sanguineous extravasation into the cranium and the cerebral ventricles, nor by the pressure of a foreign body, a tumor, or a fracture.

Symptoms.—Loss of consciousness and paralysis, which vary according to the seat and extent of the compression, are symptomatic of the condition, no matter whether the compression be sudden, like that following a wound or some mechanical injury of the skull and its contents, or whether it be slow, as that following enlargement of the brain from extravasation of blood, lymph, pus, serum, or tumors. Paralysis, excepting that of one or the other eye, is always on the side opposite to that which is the seat of injury. The symptoms may come on almost immediately after any injury of the brain that disorganizes its substance; but there are other cases in which compression takes place slowly and after a certain lapse of time. The initial symptoms that characterize this period are mainly subjective and those of congestion, as vertigo, headache, confusion of ideas, nausea, and, on rare occasions, vomiting. Then follows a lethargic sleep and more or less paralysis, and the patient cannot be aroused by any stimulus. The face is suffused and dusky, it wears an expression of well-pronounced stupor, and the eyelids are usually closed and immovable; respiration is slow, labored, and stertorous, something like the act of snoring, and the peculiar blowing movements of the lips in expiration have been compared to the act of smoking a pipe. Deglutition is impossible, and the tendon reflexes are abolished. As the intracranial trouble increases the pulse becomes slow and labored. It may be hard and frequent, or small and intermittent. Sometimes it is very irregular, and the symptoms may resemble those of anæmia of the brain and medulla, brought about by experimental means. Paralysis of the sphincters is generally present, with involuntary evacuations; or the patient may have torpidity of the bowels and obstinate constipation. Retention of urine, often present from paralysis of the bladder, is followed by incontinence as the result of overflow from distention. The skin may be cool or it may be hot and perspiring, and the temperature, though generally normal, may reach as high as 106° F. One or both of the pupils may be contracted or dilated, or they may rest immobile and unresponsive to the action of light. The symptoms of optic neuritis may also be present, and sometimes nystagmus is noted. Paralysis both of motion and of sensation, in one or both extremities, may exist in case the compression is exercised on the hemispheres, and convulsive movements and twitching of the limbs may occur on the paralyzed side or on the opposite side. Death occurs from arrest of respiration. (See *Coma* and *Asphyxia*.)

Diagnosis.—These pathognomonic symptoms, which are chiefly owing to effusion under the dura or to fracture of the inner table of the skull with resulting secondary anæmia, are not always met with, nor do such injuries as those inflicted by nails and arrow-heads driven into the skull, and even by missiles lodged in the brain, always produce the symptoms of compression. Sometimes the brain may be compressed without any disturbance of its functions. Pressure from an abscess, causing a hollow in the brain as large as a man's fist, has been known to cause no symptom of compression. It is, moreover, doubtful whether depressed fracture be a frequent cause of compression, since the injury is always complicated by laceration, the symptoms of which are often mistaken for those of compression; and it is often difficult and always embarrassing to determine, after an injury of the head, whether we have to deal with a contusion of the brain, a simple concussion, or the more problematical symptoms of cerebral compression. One state so often merges into the other that the attempt to establish a clear basis for a sure diagnosis of the respective conditions seems hopelessly confused and intricate. Roughly speaking, the most characteristic symptom of concussion is somnolence and intensity of the evil from the outset; contusion manifests itself by agitation, delirium, convulsions, contractions, and the delay of febrile symptoms; while the most salient symptom of compression is paralysis, except in the case of effusion of blood into the convexity of the hemispheres or into the ventricles, when contracture or tonic muscular spasm of extended duration is the more prominent phenomenon. Without being a sure sign, paralysis constitutes at least a valuable element in the diagnosis of a condition that has no single confirmative sign. If there be an unequivocal sign of cerebral compression in the majority of cases following injuries of the head, it is, perhaps, that furnished by obstruction of the venous circulation, in consequence of which the blood of the eye is not returned into the cavernous sinus, when we find with the ophthalmoscope papillary or peripapillary congestion, a general or partial serous infiltration of the papilla, and a strong dilatation with tortuosity of the retinal veins. (These appearances are shown in the accompanying colored plate.) In concussion the fundus of the eye retains its normal state; in compression there is always serous peripapillary infiltration, dilatation, tortuosity, and sometimes thrombosis of the veins of the retina. The intraocular changes herewith portrayed are not always pathognomonic, but they lend to the diagnosis an additional source of correctness. As a rule, when the eye-grounds show arrest of the retino-choroidal circulation, we have an indication of the arrest of cardiac circulation and of the nervous functions.

PATHOLOGY.—According to many observers, the general symptoms of compression are owing to cortical anæmia, and the general impairment of cerebral function is owing to disturbance in the capillary circulation, which prevents the normal interchange between the blood and the tissues, and results in physiological death of the affected portion of the brain. In compression, the blood may be extravasated upon the surface of the brain, the effusion taking place between the skull and the dura, and in the cavity of the arachnoid, or in the intervening spaces that separate the membranes from the brain, or it may be effused into the ventricular cavities, or into the substance proper of the brain. The volume of an extravasation between the dura and the bone is sometimes very large; but, as a rule, effusions of this kind are always much larger at the vault of the cranium than at its base. Sanguinary effusions between the dura and the bone, according to the summarized opinions of writers on the subject, generally coagulate into a firm clot that may either be absorbed or undergo organization and become adherent to both the bone and the dura. This clot never becomes encysted as do clots in the cavity of the arachnoid, but may undergo ossification. It is also susceptible of other changes. Thus, for example, it may lead to necrosis of the neighboring bones of the skull, which may be perforated by an abscess having as its foyer the sanguineous effusion.

Blood extravasated between the layers of the arachnoid, especially on that part which covers the cerebrum, is of common occurrence in the severest head injuries, and forms at the convexity of the hemisphere a thin, evenly spread layer. It clots rapidly, loses its coloring matter, undergoes organization, assuming the form of a false membrane or of a membranous cyst, and may be absorbed and take on a secreting action like other cysts.

Effusions between the visceral layer of the arachnoid and the pia are less common than those in the cavity of the arachnoid, and are generally associated with some injury of the brain itself. They spread extensively into the spaces usually occupied by the cerebro-spinal fluid, and do not become encysted as in other situations.

Traumatic effusions into the brain substance may occur in any situation. They are generally associated with laceration or other severe injury of the brain, and are for the most part fatal. Should recovery take place, the blood clot undergoes changes similar to those observed in the organization of an ordinary clot from cerebral hemorrhage.

All effusions of blood between the dura and the brain are susceptible of being reabsorbed, of being encysted in a false membrane, and of giving place to encephalitis, meningitis, and other grave symptoms that come eminently within the province of surgery; in fact, it is chiefly from this point of view that compression has been treated by the great masters.

Clinical and experimental facts show that in compression from injury of the occipital region death results not from failure of the heart, as often surmised, but from failure of the respiration. The symptoms are not mechanical but depend on trouble of circulation in the bulb, and have their point of departure in the cortex of the hemispheres including the vaso-motor centre.

In place of attributing many of the troubles grouped under the subtile heading of compression to pressure exerted upon the brain, it would be better to attribute them to congestion, to contusion, to laceration of the cerebral substance, and to interference with the function of the respiratory centre, which puts us in a position to doubt whether the effects of compression upon the brain are not susceptible of further and more convincing proof.

PROGNOSIS.—The integrity of the brain is not compromised by mere compression itself, nor is the condition a very fatal one. Its gravity depends on consecutive inflammation, secondary anæmia, and the effect on the respiratory centre. Sometimes the symptoms disappear spontaneously and gradually without interference.

The TREATMENT of compression raises many questions of operative interference, which are discussed elsewhere under their respective headings. The whole end of treatment is to restore interrupted respiration and prevent cerebral inflammation. In endeavoring to do this, artificial respiration and heat to the head by irrigation appear most commendable. *Irving C. Rosse.*

BRAIN, CONCUSSION OF THE.—(Concussion of the cord is analogous to concussion of the brain.) The term "concussion of the brain" comes down to us from the earliest ages; it was used by Hippocrates, Galen, and Celsus; its modern significance was given it by Boirel, but it was Littré who first studied the subject post mortem, in 1705.

The subject of concussion of the brain, or commotio cerebri, has received much attention from various workers, especially in the last fifty years. The theories concerning it have varied widely, even to the extent of contradiction. The general cause of this condition—traumatism—and the characteristic symptoms of the same—sudden unconsciousness, feebleness of heart and respiration—are well known; but what occurs in the cells affected is as yet undiscovered.

Verneuil, the eminent French surgeon and writer, after much observation and experience on this subject, formulates the following definition: "It is a series of phenomena occurring more or less suddenly which result from a mechanical shaking (jarring movement) of the anatomical cells, tissues, and organs, characterized by temporary excitation or depression of the properties, offices, or uses of the parts which are shaken; and as a result there are caused anatomical changes similar to those which are normally seen in the successive phases of functional activity and functional repose."

According to Pick, this term was first used because there was thought to be a shock and molecular disturbance to the cerebral tissues with no visible lesions or lacerations. This cannot hold, since the autopsy almost invariably discloses macroscopic lesions. However, these lesions are not necessarily the cause of the insensibility. It has been shown by William Savory that the state of unconsciousness and insensibility passes away, while the lesions remain. In many cases the extent of the lesion is not sufficient to produce the existing symptoms, and, again, the lesions may be present when there is no insensibility.

There are three grades: mild, severe, and fatal.

In explanation of the mildest grade the following has been offered: The cerebral cortex, owing to a momentary deprivation of nutrition, following lowered blood pressure and fall of temperature, ceases for the time being to function, and so follow loss of memory and unconsciousness.

In the more severe type the molecular disturbance is more violent and is naturally followed by graver symptoms. Mental functions are temporarily suspended, the condition of the patient somewhat resembles sleep, although the eyes are often in motion unnaturally with closed lids; or if at rest, they are not upturned and divergent as in normal individuals. This may be termed "the sleep of concussion." There is no snoring. Indeed, there may be disturbances of the cardio-pulmonary functions or paralyses of different parts of the body from localized lesions of the brain.

In the fatal form, death may follow at once or after a few hours.

ETIOLOGY AND PATHOLOGY.—The gross cause of cerebral concussion is, beyond doubt, some form of traumatism either applied directly to the head or indirectly transmitted, as in the case of a fall upon the feet—when the shock is transmitted through the spine,—or in that of a blow or a fall upon the chin. But the changes produced in the brain substance and the subsequent results have been the subjects of much argument.

Treves groups the theories of concussion under three heads:

1. Molecular disturbances.
2. Multiple hemorrhages.
3. Vascular disturbances.

In the molecular form of disturbances the brain substance is thrown into vibrations by the violence transmitted to it. The old idea that obtained, viz., that there were no macroscopical lesions, has been entirely overthrown by modern workers, for, as has been noted, in all fatal cases which come to autopsy macroscopical lesions consisting of hemorrhages or lacerations are almost invariably discovered. Not infrequently, however, these hemorrhages are too insignificant to be the cause of death or even of the symptoms of concussion. That cerebral anæmia exists is hardly disputed. The cause of this anæmia has offered a field for discussion.

Duret describes "the cone of depression and the cone of bulging," meaning by the first the point which receives the injury and by the second the area just opposite. The force of the injury imparts to the cerebrospinal fluid an impetus which drives it from the lateral ventricles into the third ventricle through the aqueduct of Sylvius into the fourth, and the latter, receiving more fluid than it loses, becomes distended. This distention causes a stimulation of the restiform bodies resulting in cerebral anæmia. Duret also believes that the small hemorrhages are due to the blood-vessels losing the support of the cerebro-spinal fluid.

Anæmia may exist by displacement of blood following the indentation of the skull. According to Fischer the loss of vascular tone may result from the nervous shock of the injury and may cause permanent vascular degeneration. Emotion is probably followed by a loss of vascular tone. The results of shock are sometimes similar. Possibly this mechanical vibration causes both physical and chemical changes in the nerve cell.

Phelps believes that the stimulation of the restiform bodies resulting in efferent reflex action causes direct capillary contraction.

After the cortical centres have received a shock there is instituted an instability of cerebral nutrition due probably to increased sensitiveness of the vaso-motor centres and a liability to anæmia or hyperæmia from very slight causes. Oftentimes individuals after head injuries are unable to undergo severe labor or exposure to the sun or the effects of alcohol. These facts were clearly recognized in the late Civil War, for men who had suffered injuries of the head were relegated to the invalid corps.

Symptoms.—The most characteristic symptoms of this condition are sudden unconsciousness, loss of memory for events just preceding or during the injury, muscular weakness, dulled sensibilities, general prostration, vomiting, and changes in the circulatory system, as illustrated by the respiration and the pulse.

These symptoms vary in their intensity and duration in accordance with the severity of the injury sustained. They may be very slight, consisting only of momentary unconsciousness, pallor, and mild interference with respiration; or they may be so severe as to be followed by death in a few moments. Treves notes three stages:

1. Stage of collapse.
2. Stage of reaction.
3. Stage of convalescence.

This is a convenient and comprehensive classification.

The clinical picture of the mildest grade is illustrated by what is familiarly known as the state of being "stunned." In this condition the patient hears strange noises, there are visual disturbances, dizziness, general weakness, inability to stand or to use the arms; the eyes lose their natural expression, the eyelids close. The pulse is always weak; sometimes it is slow, at other times it is rapid—more generally the former; and it is probable that immediately after the injury it is always slow. Respiration is disturbed, irregular, and now and then of a sighing character. The paralysis which occurs is generally only temporary as well as functional, for these phenomena disappear with returning consciousness.

In cases of well-marked concussion the superficial reflexes and knee-jerks are not pronounced, neither are the cranial reflexes. In slight cases these are sluggish.

A common symptom is delirium. This may be violent or mild, the nocturnal form being most characteristic in cases of cerebral traumatism.

In the more severe cases the symptoms are more accentuated. The unconsciousness may amount to coma, the patient being incapable of being aroused; he cannot even swallow. There are successive attacks of vomiting; the pulse is irregular, small, and generally very slow. Respiration can scarcely be detected. The skin is cold. The pupils are equal and more or less dilated, their reaction to light varying with the extent of the injury. There is incontinence of rectum and bladder, for although the sphincters of these organs are relaxed the organs themselves are not paralyzed. The temperature is the same on both sides of the body; rectal temperature is invariably subnormal, even falling to 95° F.

In the stage of reaction there is a general improvement in the bodily functions. The temperature rises, the skin becomes warm, circulation improves, respiration is stronger, and the pulse gradually becomes normal. This stage is ushered in by vomiting. Consciousness comes back by degrees, and with returning consciousness headache often supervenes. The loss of memory noted in this stage may refer only to events just preceding the receipt of the injury, or it may also include those which occurred at the time of injury. The loss of memory may continue for some time after consciousness is fully regained. During this stage the patient may die with symptoms of encephalitis or of spreading œdema. Effusion of blood may often cause death in injury to the head with or without any marked external injury. Effusions may occur upon the surface of the brain after superficial lacerations of its substance.

The duration of the stage of convalescence may be from a few days to weeks or even months. When recovery is prolonged it is fair to assume that laceration has taken place. Such an hypothesis would also account for those cases in which complete recovery never takes place and in which mental disturbances persist.

Diagnosis.—Concussion of the brain should be differentiated from opium poisoning, alcoholic coma, compression, and contusion. From opium poisoning it should be distinguished by the narrow pupils and stertorous breathing, which serve as diagnostic differences. It is often of medico-legal importance to diagnose this state from alcoholic coma. While in the latter the odor of alcohol might at first sight seem conclusive, it must not be forgotten that the brain lesion may also be present, having been received after the alcohol had been taken; also that alcohol in some form may have been given after the receipt of the injury. At all events, when a perfectly clear history pointing unmistakably to alcoholism cannot be obtained, give the patient the benefit of the doubt and treat with a view to the existence of the possible brain lesion, opium of course having been excluded.

Bourneville differentiates apoplexy and non-traumatic hemorrhages from concussion by the temperature, which is subnormal in the former, later becoming normal when recovery is to take place, but rising to an extreme degree in cases that terminate fatally; whereas in traumatic lesions the temperature rises at once while the results are uncertain.

The history will also throw much light on the diagnosis. Between concussion and compression the following table will be found to contain the points of differentiation:

Concussion.	*Compression.*
Onset of symptoms immediately after injury received.	Onset of symptoms some time after receipt of injury.
Onset sudden. Immediate unconsciousness.	Headache and drowsiness, gradually increasing to unconsciousness.
Muscular system generally relaxed, no definite paralysis.	Definite paralysis, local or general.
Pulse always weak, generally slow, sometimes rapid, and irregular.	Early slow, becoming rapid as the condition advances.
Respirations slow and shallow, may be sighing.	Early respiration is regular and slow, later becoming irregular, resembling Cheyne-Stokes
There is incontinence of urine.	Retention and overflow of urine.
The pupils are equal, dilated, and react to light.	Pupils are irregular till the last stage, then are dilated and do not react to light.
The surface temperature is equal on the two sides.	Temperature is generally irregular.

Prognosis.—The prognosis must always be guarded. In slight cases recovery is generally to be expected. Unfavorable signs are coma, very slow pulse, convulsions, and paralysis. Signs of compression and of lacerations in the stage of reaction modify the prognosis.

Treatment.—The treatment must vary with the stage at which the case is seen. If an external wound exists it must be treated, as in ordinary cases, according to its character. General directions for the stage of collapse are to regulate the depression of the circulatory and respiratory systems by means of warmth applied to the body; stimulants may be administered by the mouth if the patient can swallow; per rectum, or hypodermatically. Alcohol is contraindicated unless stimulation is indicated. The stimulants that may be used are ether, musk, strychnine, atropine, sparteine, nitroglycerin, camphor; counter-irritants such as sinapisms may be applied over the præcordium and epigastrium or to the calves of the legs. If the patient continues to be unable to swallow he may be fed through a stomach tube or per rectum. Black coffee enemata are also useful.

In the stage of reaction stimulants should be withheld, the diet should be light, and the bowels should be kept open by purgatives and enemata. Darkness and quiet are essential. When recovery is delayed shaving the head and the application of cold by Leiter's bags are to be commended; calomel and salines are beneficial.

In the stage of convalescence the patient should not be permitted to work and should be shielded from all mental excitement. Fresh air, rest, and light diet are essential.

Chloral hydrate and potassium bromide are indicated in cases of irritation. Potassium bromide aids in preventing inflammation. There must be no constriction at the neck; the head must be kept low; the scalp should be shaved and examined with care, for in fractures of the skull there are often no symptoms of a concussion for days or even weeks.

"Railway spine" or spinal concussion, formerly used to describe the results of concussion, is a misnomer.

Traumatic neurasthenia may result; this is similar to the condition following injuries to the spine when health, on account of organic disease or of overstrained nerves, is at a low ebb at the time of the injury. Traumatic inflammation of the brain or of its membranes may result. Abscesses may also follow.

Cerebral irritation is a condition sometimes following concussion. Its symptoms are probably owing to bruising of the frontal lobes. The patient lies on the side with the limbs curled up and is unconscious. He is restless and very irritable; the eyelids are closed; the pulse is slow—from 40 to 50; there is an absence of heat in the regions of the head and spinal cord; and generally there is incontinence of fæces and urine.

This condition may continue for as long a time as three weeks. The patient then extends the extremities and assumes the supine position. The temperature becomes normal, the pulse more rapid, and recovery may supervene. On the other hand, the mind may be permanently affected. There is absence of memory during the illness.

The findings at the autopsy table have been substantiated by the animal experiments performed by Koch, Fiehlene, Wittkowski, Albert, Goltz, and others.

Emma E. Walker.

BRAIN, DEVELOPMENT OF THE.—The development of the brain is bound up with that of the nervous system at large. While in the lower animals the nerve cells appear scattered or grouped in various parts of the body, and such scattered ganglion cells are found in even the highest animals, yet it is characteristic of the central nervous system as found in vertebrates that the nervous structures are collected into a common aggregate which contains only such admixture of other than nervous tissue as may serve to protect, support, and insulate the latter. It is obvious that the ordinary vegetative functions of life and many adaptive processes may be satisfactorily performed without a nervous system as such, as may be seen in the higher plants. The development of a central system, then, is an indication of preparation for higher functions than those of nutrition and metabolism or even of complex adjustment to the environment.

Early Stages.—After the egg has been differentiated into an animal and a vegetative pole and after the vegetative cells (by a process of invagination or substitute for it) have acquired an internal position, the cells remaining at the periphery (ectoderm or epiblast layer) represent the rudiments from which are to spring all the cells and specific organs not only of the central nervous system but of the sensory apparatus which forms the avenue from the external world to the central system. The ectoderm also contains, of course, the forerunners of the cells of the epidermis at large.

In general, the rudiments of the central nervous system collect in a broad longitudinal band extending along the dorsum of the embryo, while the rudiments of the sense organs exhibit a tendency to be arranged in one or more series along either side of the central band or medullary plate (Fig. 822).* In lower, especially aquatic, forms this lateral sensory band is evident in late life as the series of lateral-line organs, and it is plain that some or all of the organs of special sense obey the same law of serial arrangement, the ear in particular betraying relationships to the lateral-line system. (Compare Vol. I., p. 627.)

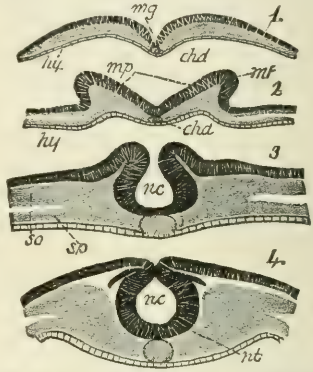

Fig. 822 (Nos. 1 to 4).—Transverse Sections through the Neural Plate and Neural Tube of an Embryo Bird. *chd*, Notochord; *hy*, entoderm; *mf*, neural folds; *mg*, neural groove; *mp*, neural plate; *nc*, neural canal; *nt*, neural tube; *so*, somatopleure; *sp*, splanchnopleure. (Mihalkovics and Balfour.) In No. 4 the rudiment of the spinal ganglia is represented but not lettered.

The Neural Plate and Tube.—The neural or medullary plate is supported from below by a band of cells derived from the original entoderm which separates from the latter to form a solid rod (perhaps theoretically a tube at one stage), called the chorda dorsalis. The medullary plate grows more rapidly than the adjacent ectodermal tissue, and thus forms a raised border on either side with a groove in the median dorsal line. This medullary groove is continuous behind with the lip of the blastopore or opening left after the invagination of the entoderm. As the lateral margins of the medullary groove rise higher above the surface (both nervous and epidermal portions participating in the growth), the groove is transformed into a tube. The concrescence of the lips of the fold begins at a point corresponding with the site of the future midbrain. In the vicinity of the blastopore the groove may remain open for some time, and there is formed a direct communication with the primitive digestive tract through what is known as the canalis neurentericus, a

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* These and several of the following cuts are introduced without change from the article by Professor H. F. Osborn in the former edition.

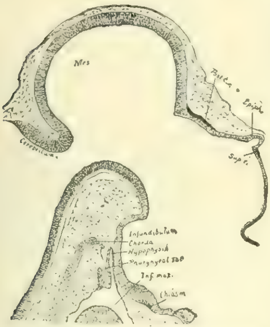

FIG. 823. Median Section of Brain of Bird Embryo, to Show Hypophysis and Pharyngeal Sac.

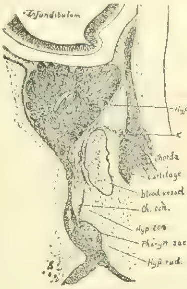

FIG. 824.—Later Stage of Hypophysis.

communication that is disturbed only by the final closing of the blastopore. At the cephalic extremity also the closing of the tube is long delayed, and there is left an opening called the neuropore communicating with the exterior at the front of the head.

In bony fishes and other vertebrates whose eggs have much yolk, the tube may be formed first as an apparently solid cord of cells, but the final result is the same.

At the cephalic extremity of the digestive tract, which at this stage ends in a blind sac separated from the pharyngeal invagination by the portion of the ectoderm known as the septum of Remak, is a region of fusion called the *area reuniens.* Here the cephalic end of the chorda, the base of the brain tube, and the angle of the enteric cavity tend to adhere temporarily. On the cephalic side of the septum the ectoderm gives rise to (an apparently single) median invagination which extends dorsally to meet a similar outgrowth of the infundibular region of the brain, combining with the latter to form the hypophysis or pituitary body. On the opposite side of the septum a somewhat similar outgrowth from the cephalic dorsal angle of the digestive tract forms the so-called Seessel's sac, which in some cases seems to connect with the cephalic end of the chorda. In birds at least this sac is distinct from the chorda which subsequently degenerates and leaves a convoluted thread-like vestige behind it that is closely connected with the site of origin of Seessel's sac. The latter, after the breaking through of the septum, comes, in birds, to lie in connection with the base of the hypophysis (Fig. 823).

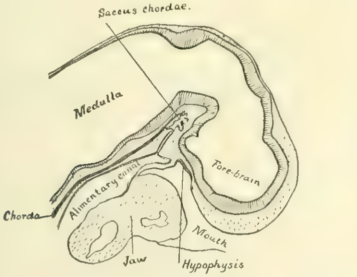

FIG. 825.—Illustration Showing the Relation between Chordal Sac, Alimentary Canal, and Brain Flexure in Opossum. (From Selenka.)

This region seems to mark the morphological front of the head, and the medullary tube is often open at front, forming a neuropore (Fig. 826). Gradually the tube extends cephalically, and the base and roof unite along a line a part of which becomes that part of the base of the brain occupied by the postoptic and preoptic recesses, the remaining part being the lamina terminalis (Fig. 826). The portion of the brain developed cephalad of the area reuniens, *i.e.*, in front of the cephalic end of the chorda, is called the prechordal as distinguished from the remaining, or epichordal part of the brain, and is morphologically different from the latter. In early stages of the development of the brain tube it appears segmented, and many attempts have been made to prove that these segments, or neuromeres, have a morphological significance and that they correspond with the segments discoverable in other and especially the mesodermal tissues. It has also been supposed that evidence of this primitive segmentation could be seen in the arrangement of the roots of the cranial nerves. On the whole, however, it must be admitted that, while it is not difficult to detect the segmental arrangement in the epichordal part of the brain, the prechordal portion either was not derived from

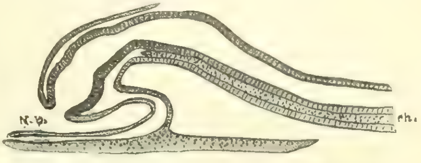

FIG. 826. Brain of Torpedo, to Show the Neuropore, *n.p.*

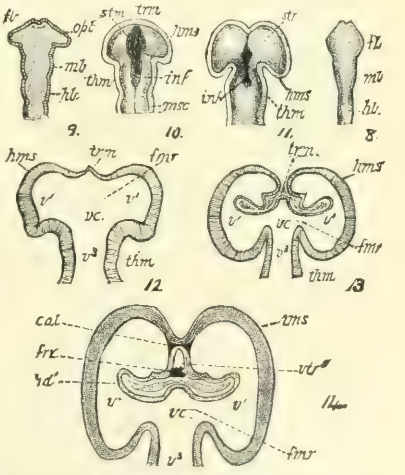

FIG. 827 (Nos. 8 to 14).—Horizontal Sections of the Forebrain (8 and 9, of a bird; 10 to 14, of a rabbit). (Kölliker, Mihalkovics, Lowe.) *cal*, Corpus callosum; *chd*, choroid plexus; *fmr*, foramen of Monro; *frx*, fornix; *hms*, cerebral vesicle, hemisphere; *inf*, infundibulum; *msc*, mesencephalon; *stm*, stem; *str*, corpora striata; *trm*, lamina terminalis; *thm*, optic thalami; *vc*, ventriculus communis; *vtr*^{5}, fifth ventricle; *v′*, lateral ventricle; *v*^{3}, third ventricle. Other letters as above.

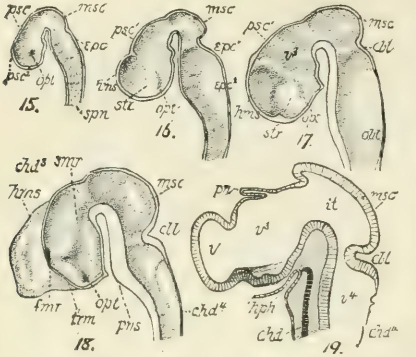

FIG. 828 (Nos. 15 to 19). Vertical Sections of the Brain (15 to 18, of the rabbit; 19, of the bird) (Mihalkovics.) *cbl*, Cerebellum; *chd*^{4}, tela vasculosa; *chd*^{3}, choroid plexus of third ventricle; *epc*, epencephalon; *hph*, hypophysis; *it*, iter; *psc*^{2}, prosencephalon; *psc*^{1}, diencephalon; *pns*, pons Varolii; *smr*, sulcus of Monro; *v*^{4}, fourth ventricle.

a segmented rudiment, or, if so, it has suffered such complete alteration as to prevent the identification of the neuromeres.*

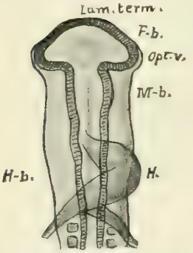

FIG. 829.—Dorsal View of Chick of Fifty-Eight Hours. (After Mihalkovics.) *Lam. term.*, Lamina terminalis; *F-b.*, forebrain; *Opt. v.*, optic vesicle; *M-b.*, midbrain; *H.*, heart.

In all vertebrates the portion of the medullary tube destined to become brain is divided at an early stage into three embryonic vesicles, the forebrain, midbrain, and hindbrain respectively (Figs. 827 and 829). In all higher vertebrates the midbrain is the site of a very important flexure which is formed at an early embryonic stage and causes the forebrain to assume a ventral position with reference to the remainder of the brain. The division into three lobes homologous with the vesicles may take place in some cases before the closing of the tube, but this may be looked upon as an instance of retardation in the development of the tube and is of no morphological significance.

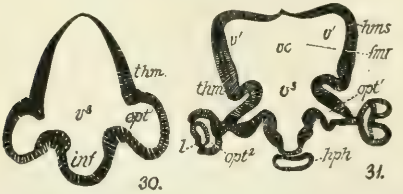

FIG. 830 (Nos. 30 and 31).—Transverse Sections through the Forebrain of a Rabbit, Showing the Development of the Optic Vesicles and Rudimentary Parts of the Eye. (Kölliker.) *l*, Lens; *hph*, hypophysis; *opt*^{1}, primary optic vesicle; *opt*^{2}, secondary optic vesicle.

Embryonic Brain Zones.—After the closing of the medullary tube the dorsal and ventral median portions are thinner than the lateral walls and have been called by His basal plate and roof plate respectively, though they are rather lines or zones than plates. On either side the walls are divided into a dorsal and a ventral zone, called respectively fundamental and alar zones or plates. The fundamental plate is the site for the development of the motor cells and is the zone of origin for the ventral or motor nerve roots, while the alar plate includes the zone of the sensory roots.

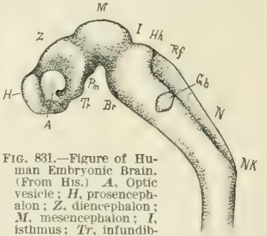

FIG. 831.—Figure of Human Embryonic Brain. (From HIS.) *A*, Optic vesicle; *H*, prosencephalon; *Z*, diencephalon; *M*, mesencephalon; *I*, isthmus; *Tr*, infundibulum; *Pm*, mammillare; *Br*, pons; *Hh*, cerebellum; *Rf*, roof of fourth ventricle; *Gb*, auditory vesicle; *N*, medulla; *Nk*, cervical flexure.

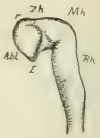

FIG. 832.—Youngest Stage of Ichthyophis. *I*, Infundibulum; *Abl*, optic vesicle; *Zh*, diencephalon; *Mh*, mesencephalon; *Rh*, metencephalon.

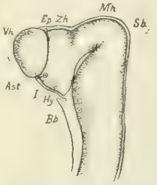

FIG. 833.—An Older Embryo of Ichthyophis. *Ep*, Epiphysis; *Ast*, optic peduncle; *Sb*, mesencephalic flexure; *Bb*, pons flexure.

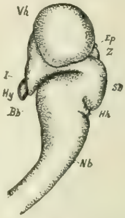

FIG. 834.—Embryo of a Still Later Stage.

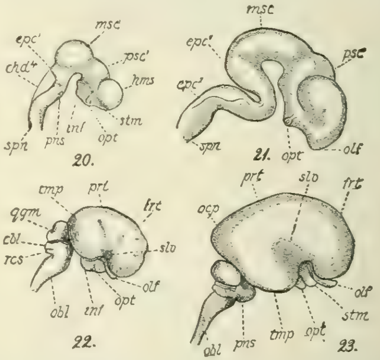

FIG. 835 (Nos. 20 to 23).—Lateral Views of the Brain (20, of a bird; 21, 22, of a human embryo; 23, of a pig). (Mihalkovics.) *frt*, Frontal lobe; *ocp*, occipital lobe; *olf*, olfactory lobe; *prt*, parietal lobe; *qgm*, corpora quadrigemina; *obl*, medulla oblongata; *prt*, parietal lobe; *rcs*, recessus lateralis; *slv*, Sylvian fissure; *spn*, spinal cord; *tmp*, temporal lobe. Other letters as above.

That part of the base of the brain tube which is adjacent to the area reuniens forms an expansion in a ventral, caudal, and cephalic direction, giving rise to the fundus basi

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* Locy and his school identify eleven neuromeres in the brain, five of them being cephalad of the cerebellum.

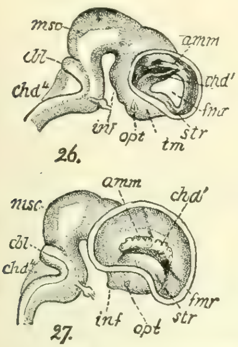

FIG. 836 (Nos. 26 and 27). Lateral Views of the Brain, with the Lateral Ventricles Exposed. (Mihalkovics.) *amm*, Cornu ammonis; *tm*, stem. Other letters as above.

laris with a cephalic extension, the recessus opticus, and a caudal prolongation, the recessus infundibuli. The recessus opticus is divided into the preoptic and the postoptic division by the chiasm. At the apex of the infundibulum is the place of the pituitary, while the tuber cinereum with its olfactory connections develops behind the infundibulum. In amphibia the infundibulum is produced caudad to form the saccus vasculosus. In fishes the so-called lobi inferiores appear behind the infundibulum, but these have no relation to either the infundibulum or the cinerea, as has been supposed, but are diverticles from the walls of the pes.

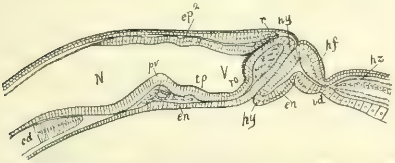

FIG. 837.—Median Section of Embryo of Acipenser Sturio, Forty-Five Hours After Fertilization.

Roof of the Brain.—The dorsal walls of the brain naturally develop more rapidly than the base. The roof of the hindbrain for a large part of its length fails to develop nervous elements, but remains membranous and forms the velum medullare posterius or kilos. This membrane becomes associated with a rich plexus of blood-vessels, and together these penetrate the cavity of the hindbrain (fourth ventricle), and furnish the vascular supply to that region. The triangular form of the velum, where its sides converge to the point where the solid parietes meet, has given rise to the term calamus for this locus. Cephalically the latero-dorsal walls of the hindbrain thicken and are reinforced by outgrowths of ventricular epithelium to form a paired body which becomes apparently single by the concrescence of the two halves. This is the cerebellum. In amphibia the cerebellum remains obsolescent and its development varies greatly in the different groups; but in general it can be seen that the relative development of this organ is commensurate with the necessities for motor coordination. In birds, for example, it is highly developed, while the brain as a whole remains upon a rather low plain of development. Immediately cephalad of the cerebellum is the velum medullare anterius or valvula in which the fibres of the fourth nerve ultimately decussate and from which there is developed in many fishes a remarkable invagination into the cavity of the midbrain known as the volvula. The roof of the midbrain becomes thickened laterally and divides into a cephalic and a caudal portion. The larger or tectal portion in lower vertebrates forms two hemispherical projections connected by the Sylvian commissure and receiving the fibres from the optic brachia or extensions of the optic nerves. The caudal portion has a solid structure, and is composed of a mass of nerve cells

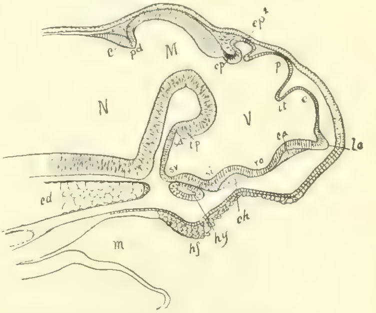

FIG. 839.—Similar Section of Larva, Three Days Old.

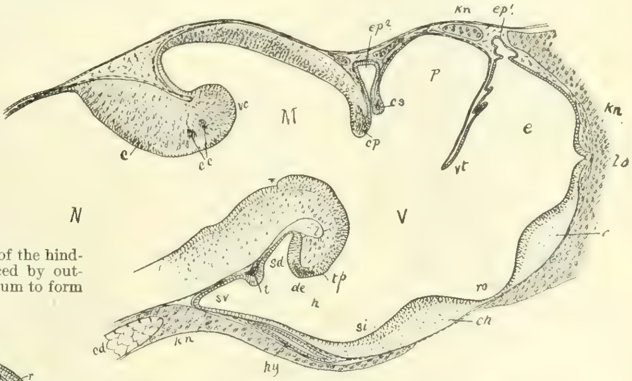

FIG. 840.—Similar Section of Larva, Four Weeks Old.

Description of Figs. 837 and 840. *c*, Cerebellum; *ca*, precommissura; *cc*, commissura cerebelli; *cd*, chorda dorsalis; *ch*, chiasm and commissura postopticæ; *cp*, postcommissura; *cs*, supracommissura; *dc*, commissura debilis; *e*, cerebrum; *en*, entoderm; *ep*¹, paraphysis; *ep*², epiphysis; *h*, hypencephalon = infundibular region; *hf*, sucking disc; *hy*, hypophysis; *hz*, heart; *kn*, cartilage; *lo*, lobus olfactorius impar.; *M*, mesencephalon; *m*, mouth; *N*, metencephalon; *p*, præpineal roof of diencephalon (parencephalon); *pd*, plica dorsalis; *pv*, plica ventralis; *r*, median olfactory plate; *ro*, recessus opticus; *si*, sinus postopticus; *t*, commissura terminalis; *tp*, tuberculum posterius; *v*, prosencephalon; *vt*, velum transversum of the forebrain.

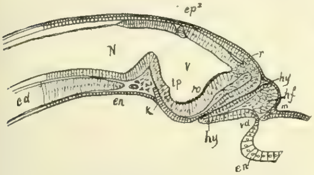

FIG. 838.—Similar Section of Embryo, Sixty-Four Hours After Fertilization.

embedded in a stroma. This nucleus tends to drop below the surface, and it is probable that in it are found the reflex connections for the optic apparatus.

In mammals the roof of the midbrain is occupied by two pairs of eminences, together constituting the corpora quadrigemina, and the representatives of the tectum seem to be scattered among several adjacent parts of the midbrain walls. This is a region especially in need of study.

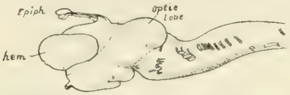

FIG. 841.—Lateral View of the Brain of Adult Petromyzon. *Epiph*, Epiphysis; *hem*, hemisphere; *optic lobe*, optic lobes.

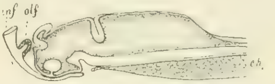

FIG. 842.—Longitudinal Perpendicular Section of the Brain of Ammocœtes, for comparison with the brain of Amphioxus. *ch*, Chorda; *olf*, olfactory sac; *inf*, infundibulum.

Immediately cephalad of the tectum is the postcommissure in which decussate part of the fibres of the dorsal longitudinal fasciculus. The roof of the forebrain is divided into a cephalic and a caudal portion by the evagination of the epiphysis. The latter always arises just caudad of the supracommissure, but varies in form and relations in the different groups. In many lizards it gives rise to the parietal organ, or "pineal eye." In snakes it becomes highly vascularized and glandular, while in mammals it appears to undergo retrograde metamorphosis. Near the supracommissure, in the roof of the first vesicle, there develop clusters of cells forming the habenulæ. These nuclei are asymmetrically developed and sustain some relation to the pineal. From them or a group of cells closely associated arises Meynert's bundle (fasciculus retroflexus). Another mass of cells, called the subhabenular nucleus, arises in the deeper walls nearer the ventricle.

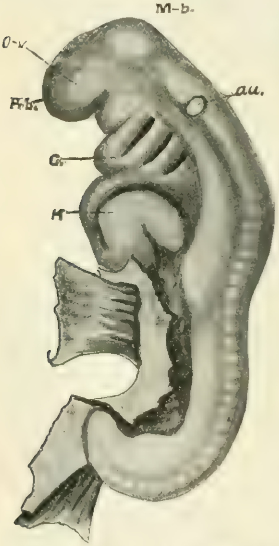

FIG. 843. Human Embryo 4 Mm. Long. *M-b.*, Midbrain, flexure already developed; *O-v.*, optic vesicles; *F-b.*, forebrain; *Au.*, auditory vesicle; *H.*, heart; *C.*, pharyngeal clefts.

Cephalad of the supracommissure the roof tends to be membranous and gives rise to various outgrowths in different groups (the paraphyses) and to an ingrowing velum which with its vascular associates gives rise to the choroid plexus. Through this portion of the roof, connecting the two sides, there pass, first, the hippocampus commissure or fornix, and, in higher vertebrates at least,

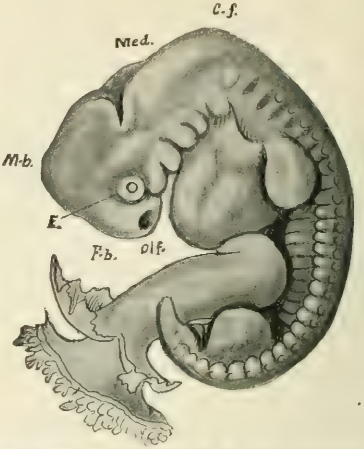

FIG. 844.—Human Embryo Older than Fig. 843. *M-b.*, Midbrain; *Med.*, medulla oblongata; *C-f.*, cervical (or nuchal) flexure; *E.*, eye; *F-b.*, forebrain; *Olf.*, olfactory pit.

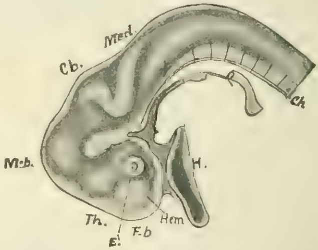

FIG. 845.—Similar View of an Earlier Embryo. *ch*, Chorda dorsalis. Other letters as above.

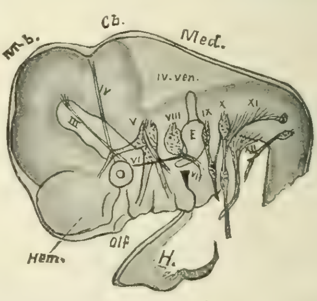

FIG. 846.—Embryo (Older than Fig. 843) Seen as Transparent. *M-b.*, Midbrain; *Hem.*, hemispheres; *Olf*, olfactory pit; *Cb.* cerebellum; *Med.*, medulla; *H*, heart; *IV. ven.*, space occupied by fourth ventricle; *E*, auditory vesicle. The cranial nerves are numbered.

the corpus callosum. The lamina terminalis contains the precommissure.

Such, in brief, is the course of development of the brain stem, but we may pass to the consideration of the several portions separately.

The Forebrain.—At an early stage the lateral walls of the forebrain evaginate on either side to form the primary optic vesicles, which give rise in time to the retina and the choroid coat of the eye (Figs. 829 and 830). For some time the brain vesicle remains in communication with the optic vesicles through the hollow stalks of these outgrowths, and in the amphibia the optic stalks remain hollow though clothed exteriorly with the fibres of the optic nerve.

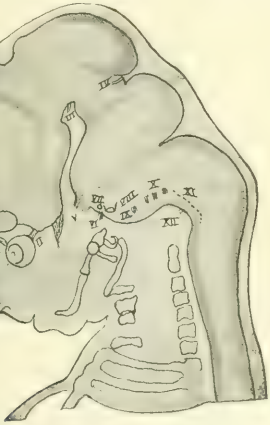

FIG. 847.—The Brain of a Human Embryo 20 mm. Long.

Their connection with the brain is near the base cephalad of the infundibulum. Cephalad of the points of origin of the eyes a second pair of evaginations form the rudiments of the hemispheres. These spheroidal pouches, separated from each other by the lamina terminalis, rapidly increase in size and soon outstrip all other parts of the brain. The communication between the ventricles of the hemispheres and the remnant of the forebrain vesicle is at first direct through the portæ, but at a later period the two portæ come to open into a median recess narrowed off from the first vesicle and called the aula (see Fig. 860). What remains after the development of the eye vesicles and hemispheres is the thalamus or diencephalon, while the hemispheres collectively constitute the prosencephalon. (Another usage embraces the thalamus and hemispheres under the term prosencephalon and applies the term telencephalon to the hemispheres.)

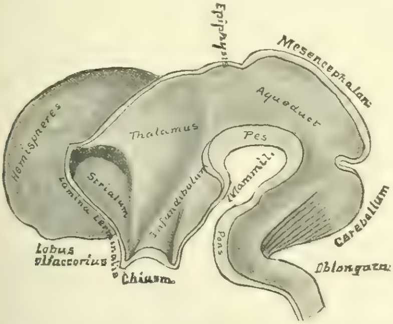

FIG. 848.—Diagrammatic Median Section of the Brain of a Human Embryo.

At first the walls of the medullary tube are apparently nearly homogeneous, but after the separation of the various outgrowths the rate of development proceeds very differently in various parts. Thus, in the walls of the hemispheres certain areas develop with great rapidity while others are retarded. In the basilateral walls of the hemispheres especially there develop masses of cells which give rise to projections into the ventricles (Figs. 829 and 830). In this way a distinction is produced between the axial lobes of the cerebrum and the mantle portion. From the axial lobes arise in mammals the corpora striata through which pass the bundles of fibres from the cortex to lower centres and from the cord and lower parts of the brain to the cortex (see Fig. 859). Elsewhere in the cerebrum the development tends to cause the cells to collect on the peripheral aspect, and thus is formed the cortex cerebri, the most important portion of the brain from a psychical point of view, though from the physiological standpoint it may seem rather an epiphenomenon or afterthought.

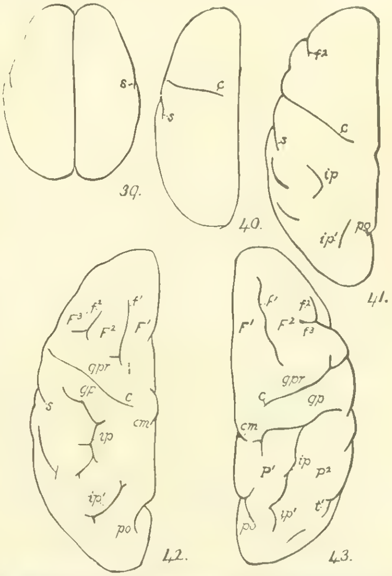

FIG. 849 (Nos. 39 to 43).—Development of the Fissures on the Upper Surface of the Hemispheres. No. 39, at sixteen weeks; No. 40, at twenty weeks; No. 41, at twenty-three weeks; No. 42, at the middle of the seventh month; No. 43, at the close of the seventh month. (Ecker.) *c*, Sulcus centralis; *cm*, calloso-marginalis; f^1, s. frontalis superior; f^2, s. frontalis inferior; f^3, s. praecentralis; F^1, gyrus frontalis superior; F^2, g. frontalis medialis; F^3, g. frontalis inferior; *gp*, g. postcentralis; *gpr*, g. praecentralis; *ip*, g. intraparietalis; ip^1, g. intrap. posterior; P^1, g. parietalis superior; P^2, g. par. inferior; *po*, s. parieto-occipitalis; *s*, fissura Sylvii.

Fissures of the Cerebrum.—As a result of the rapid and unequal growth of the hemispheres they are at first bodily flexed about a horizontal axis afforded by the line of attachment to the axial portion of the brain. The first result of this flexure is the formation of the Sylvian flexure and fossa. This is one of the most important landmarks in the brain, giving rise to a depressed region of cortex (the insula) covered by flaps (the opercula) and marked in the adult brain by the fissure of Sylvius. Here is located (on the left) the motor speech centre (Broca's region). On the dorsal surface, extending from the dorsal margin obliquely toward the fissure of Sylvius, is the compensating fissure of Rolando (sulcus centralis), the convolutions adjacent to which contain the most important centres for voluntary motion. By means of these landmarks the "lobes" of conventional anatomy are indicated at an early period. Instead of going farther into details as to the sequence of development of the fissures and convolutions we venture to quote from Dr. J. D. Cunningham,[*] who, in the "Memoirs of the Irish Academy of Science" bearing his name, gives an extended account of the comparative development of the surface anatomy of the cerebral hemispheres. We condense from this work the following statements:

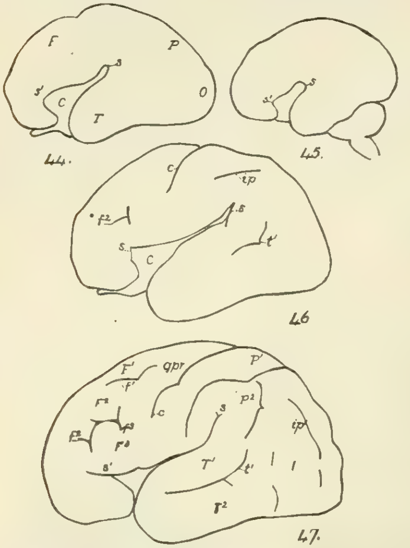

FIG. 850 (Nos. 44 to 47).—The Development of the Convolutions on the Sides of the Hemispheres. No. 44, at sixteen weeks; No. 45, at twenty weeks; No. 46, at twenty-three weeks; No. 47, at the close of the seventh month. S^1, Anterior branch of the Sylvian fissure; T^1, g. temporalis superior; T^2, g. temporalis inferior; t^1, temporalis superior. (Ecker.)

Complete Fissures ("Total-Falten").—The transitory fissures which appear in an early period of the development of the hemispheres are distinguished by the fact that they are a result of a series of deep infoldings of the thin cerebral wall and form shelf-like projections into the ventricles.

Under normal conditions none of the fissures which appear on the lateral aspects of the hemispheres persist in the adult, though in the ape two at least are persistent. Upon the mesal aspect, on the contrary, the choroid, a portion of the arcuate, and sometimes the parieto-occipital with part of the calcarine fissures persist. The choroid and arcuate appear as early as the fifth week. The choroid fissure occupies the lowest limit of the mesal wall, reaching the porta, cephalad, and extending caudad nearly to the extremity of the temporal lobe. Though not at first occupied by blood-vessels, and therefore not formed by them, its walls do not develop into nervous tissue but remain epithelial and are occupied by this preplexus. The fissura arcuata (*Ammonsfurche* of Mihalkovics) makes its appearance on the mesal face of the hemisphere at a higher level than the choroid fissure, and while it extends, like the preceding, into the temporal lobe, it also passes cephalad into the frontal region. That portion of the hemisphere which lies between the two fissures mentioned is termed the *arcus marginalis*, in connection with which are formed the callosum, the gyrus dentatus, and the fornix.

The caudal part of the fissure arcuata is retained in adults as the hippocampal fissure, and gives rise to the elevation in the floor of the descending cornu known as the hippocampus major.

The remainder of the complete fissures are transitory. The mesal wall of the hemispheres being thicker than the outer, the transitory fissures there first appear. They may appear as early as the eighth week, and reach a high degree of development only after the tenth week. Their maximum development is reached between the periods when the fornix and callosum appear, *i.e.*, near the beginning of the fifth month.

On the mesal aspect of the hemispheres the transitory fissures, which vary in number, radiate from the arcuate fissure toward the free border of the hemisphere, and others, lying between them, but not connecting with the arcuate fissure, appear near the margin. The usual number on each hemisphere appears to be eight.

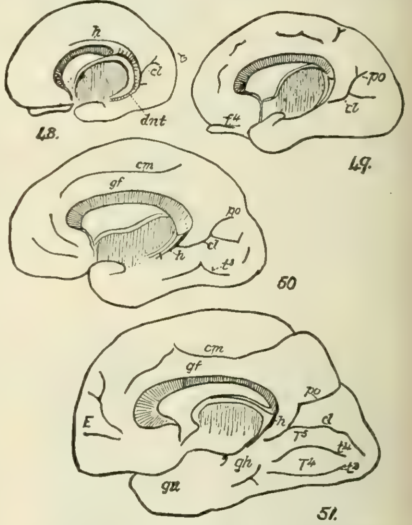

FIG. 851 (Nos. 48 to 51).—The Convolutions on the Inner Surfaces of the Hemispheres. No. 48, at sixteen weeks; No. 49, at twenty weeks; No. 50, at twenty-three weeks; No. 51, at the end of the eighth month. *cl*, Fissura calcarina; f^4, s. olfactorius; *gf*, g. fornicatus; *gh*, g. hippocampi; *gu*, g. uncinatus; *h*, s. hippocampi; t^3, s. temporalis inferior; t^4, s. occipito-temporalis inferior; T^4, g. occipito-temporalis lateralis; T^5, g. occipito-temporalis medialis.

The primitive fissures which bound the cuneus are the precursors of the calcarine and parieto-occipital fissures. As the wall of the cerebral vesicle thickens, and the hemisphere elongates, the stellate fissures become detached from the arcuate fissure and gradually disappear.

Upon the outer aspect the arrangement of the fissures is also radial, with the Sylvian fossa as the centre, but these fissures usually do not reach the fossa. There is frequently an additional fissure occupying the place of the future Sylvian. In some cases the precursor of the calcarine is carried horizontally around the occipital pole, appearing on the lateral surface as an external calcarine fissure.

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[*] "Contribution to the Surface Anatomy of the Cerebral Hemispheres," J. D. Cunningham, Cunningham Memoirs of Royal Irish Academy, vii.

It is regarded as probable that under abnormal conditions, as when the callosum fails to develop, the transitory fissures may persist to a certain extent. The fact emphasized by Sir William Turner, that in *Macropus*, where the callosum is rudimentary, the radiating fissures resemble those of an immature human brain, is at least suggestive that the development of the callosum has some effect on the disappearance of these fissures.

Dr. Cunningham fully agrees with His and Kölliker that the occipital lobe is due to a general growth and not a local outpouching of the hemisphere; its peculiar form is due to the transformations produced by axial flexures —especially the pons flexure. This backward thrusting of the posterior part of the hemisphere is chiefly responsible for the preservation of the precursory calcarine and parieto-occipital fissures. The temporary fissures are in all probability peculiar to primates, and appear prior to the appearance of a distinct occipital lobe.

The parieto-occipital and calcarine fissures form upon the mesal aspect of a posterior part of the adult hemisphere a >— shaped figure. The stem is directed obliquely ventrad and intersects the gyrus fornicatus. The parieto-occipital fissure forms the more direct continuation of the stem, and continues on the ectal surface as the external parieto-occipital fissure. The calcarine branch passes toward the occipital pole. The stem is called the anterior calcarine fissure. The apex of the cuneus gives off two deep annectant gyri—the gyrus cunei and anterior cuneo-lingual gyrus. The gyrus cunei forms a barrier between the parieto-occipital fissure and the stem, while the gyrus cuneo-lingualis anterior separates the stem and the posterior part of the calcarine fissure.

The calcar (hippocampus minor) is formed wholly by the stem or anterior calcarine fissure.

In apes the calcarine fissure is deep and much more stable than the parieto-occipital. In the chimpanzee the gyrus cuneus is on the surface (a condition found in 3.9 per cent. of human brains), while in the orang and gibbon the cunei may be on the surface or at the bottom of the fissure. The gyrus cunei is never absent. Cunningham believes that the whole calcarine fissure of anthropoids corresponds to the "stem" of the human calcarine; or rather, the whole length of the precursor of the human calcarine is the equivalent of the ape calcarine. The posterior calcarine of man is of later origin and takes the place of an abolished portion of the original fissure. The cuneus of the ape does not have the same morphological value as that of man. Only the cephalic part is present in the ape; the caudal part is absent or blended with the gyrus lingualis. In the ape the entire length of the calcarine fissure is on the tentorial face of the hemisphere.

The posterior calcarine fissure is distinct from the "stem" in origin, the latter being a "complete fissure" and having unbroken continuity of existence with the fore-part precursor.

The Occipital and Parietal Indices are the distances along the mesal margin of the hemisphere intercepted by the intersection of the external parieto-occipital fissure and the fissure of Rolando respectively; in the first case the measurement being taken from the occipital pole, in the second from the parieto-occipital intersection, and both these distances being given in terms of hundredths of the entire length along the dorsal margin of the hemisphere.

For the human brain the following averages are given:

5½ to 6½ months	O. index, 18.8;	P. index, 28.5.
6½ to 7½ months	" 18.6;	" 24.7.
7½ to 8½ months	" 20.7;	" 24.1.
Full-time fœtuses	" 20.8;	" 25.7.
First 12 months	" 22.3;	" 25.6.
4 to 5 years	" 23.2;	" 24.2.
11 to 15 years	" 20.8;	" 27.4.
Adults	" 21.2;	" 25.5.

For apes the following table is given:

Orang	O. index, 23.2;	P. index, 21.3.
Chimpanzee	" 24.2;	" 19.9.
Hamadryas	" 29.5;	" 20.5.
Cynocephalus	" 29.7;	" 22.6.
Mangaby	" 30.5;	" 24.1.
Macaque	" 31.0;	" 19.0.
Cercopithecus	" 32.9;	" 19.0.
Cebus	" 33.1;	" 20.6.

The low parietal index and high occipital index are instructive features. In low apes there is an enormous increase in the occipital portion of the border; whereas in the high apes the amount of increase is smaller. The relative shortness of the parietal border in high apes is due to the relative increase of the occipital and frontal borders. In low apes the reduction of the parietal portion is entirely due to the great size of the occipital lobe.

The following summary is reproduced verbatim:

1. At an early period in the development of the cerebral hemisphere a series of deep infoldings of its thin walls make their appearance. On the exterior of each hemisphere these show in the form of sharply cut linear fissures.
2. Certain of these fissures are permanent; the great majority are transitory.
3. The transitory fissures, with two exceptions, have disappeared by the time the corpus callosum is fully formed.
4. A deficiency of the corpus callosum is associated with a persistence of the temporary fissures.
5. The temporary fissures indicate an important stage in the growth of the cerebrum, and are apparently associated with the mapping out of the occipital lobe.
6. A quadrupedal pause in the growth of the cerebrum brings the skull capsule into antagonism with the growth of the hemispheres, and, in consequence, the wall of the cerebrum is thrown into folds. These folds disappear as the occipital lobe assumes shape, owing to the expansion of the cranial cavity, and a restoration of growth harmony between skull and brain.
7. Consequently it is only in Primates, which alone possess well-developed occipital lobes, that transitory infoldings of the cerebral walls in all probability exist.
8. The two transitory fissures which do not disappear before the full development of the corpus callosum are: (*a*) the external calcarine, and (*b*) the external perpendicular fissure of Bischoff. In point of fact the latter fissure does not appear until after the full development of the corpus callosum.
9. The external calcarine fissure produces an infolding of the outer wall of the posterior horn of the lateral ventricle, which presents the same direction, and lies immediately opposite to the true calcarine infolding, or the calcar avis.
10. The fissure corresponding to this in apes is, as a rule, permanent, and in some species its anterior end forms in the adult a bulging on the outer wall of the ventricle.
11. The external calcarine fissure disappears before the sixth month of fœtal life in man.
12. The external calcarine fissure is present on the outer surface of the fœtal cerebrum from the beginning of the fifth month to the end of the sixth month.
13. It is a complete fissure and corresponds to the "Affenspalte" on the ape's brain.
14. The "Affenspalte" on the ape's brain is also a complete fissure, and presents a well-marked bulging on the outer wall of the posterior horn of the ventricle; but, unlike the external perpendicular fissure of the human fœtus, it is permanent.
15. Certain fissures, therefore, which are complete and temporary in the human brain, are complete and permanent in the ape's brain.
16. The complete permanent fissures in the human are: (*a*) the fore part of the calcarine; (*b*) the hinder part of the fissura arcuata; (*c*) in many cases the parieto-occipital; and (*d*) in some cases the midcollateral. The Sylvian fissure is not a complete fissure.

17. Of the fissura arcuata the hinder part alone is preserved as the fissura hippocampi. The fore part, which is generally supposed to be retained as the callosal fissure, is in reality obliterated.

18. Synchronous with the appearance of the radial transitory fissures on the mesal face of the hemisphere two fissures appear, which lie in series with the former and occupy the ground afterward held by the parieto-occipital and calcarine fissures. These may be termed the precursors of these fissures.

19. The precursor of the parieto-occipital fissure sometimes shows an unbroken continuity of existence with the parieto-occipital fissure of the adult brain. In other cases it is obliterated, and its place is afterward taken by a secondary sulcus, which attains, however, a very great depth.

20. In the adult brain the parieto-occipital fissure, even in its complete form, does not form any eminence on the inner wall of the posterior horn of the ventricle, because it does not extend downward as far as the cavity. Above its lower end the hemisphere is solid.

21. The posterior end of the calcarine precursor is in every case obliterated, and the anterior part retained. The extent of the part obliterated varies considerably in different brains.

22. The anterior preserved portion of the calcarine fissure forms the "stem" of the >— shaped fissural arrangement on this part of the hemisphere, and its hinder part corresponds to the calcar avis.

23. In the place of the hinder portion of the calcarine precursor, which is obliterated, a secondary furrow appears. This may be termed the posterior calcarine sulcus.

24. The posterior calcarine sulcus is formed in two pieces which run together and also form the "stem." In this way the entire length of what in anatomical language is called the calcarine fissure is formed.

25. The posterior calcarine sulcus is not a complete fissure.

26. In the ape the entire length of the calcarine fissure is represented by that portion of the fissure which in man is termed the "stem," and by that alone. The posterior calcarine sulcus does not exist in any form in the apes.

27. The cuneus, therefore, has a different morphological value in the apes and in man. In connection with this compare the abnormal human hemispheres. These exhibit certain conditions which approximate to those present in the apes.

The Fossa and Fissura Sylvii.—The sign of the Sylvian depression appears at the end of the second month of development. Dr. Cunningham summarizes his investigation as follows:

"1. As growth proceeds the outline of the Sylvian fossa changes considerably. At first nearly circular, it elongates in a vertical direction and then backward on itself, and assumes a triangular outline.

"2. The high prominent mantle border or rim which surrounds the depression is divided by intervening angles into four sections, viz.: the *temporal* (postoperculum), or lower; the *fronto-parietal* (operculum), or upper; the *frontal* (preoperculum), which is formed by an opening out and flattening of the primitive single anterior angle; and an *orbital* (suboperculum), or front portion.

"3. Each of these portions of the bounding rim acts as an independent line of growth, and consequently, in course of time, four opercula grow over the Sylvian area so as to enclose it. The temporal and fronto-parietal opercula appear first; the frontal and orbital do not develop until a much later period.

"4. The so-called three limbs of the fissure of Sylvius are formed by the meeting over the Sylvian area of the contiguous lips of the four opercula; the posterior horizontal limb intervenes between the fronto-parietal and the temporal opercula; the anterior ascending limb between the frontal and fronto-parietal opercula; the anterior horizontal limb between the frontal and the orbital opercula.

"5. The frontal operculum is therefore the same as the 'cap de Broca,' and it shows great variations in its length. It may be absent altogether, and then the two anterior limbs of the Sylvian fissure are fused into one. When the frontal operculum is reduced in length we have the **Y**-condition of the two anterior Sylvian rami.

"6. The Sylvian fossa once mapped out on the surface of the hemisphere, it extends very rapidly. The growth is not proportionate with that of the hemisphere, it is much more rapid.

"7. During intrauterine life the anterior end of the insula maintains a very nearly fixed position with reference to the anterior end of the cerebrum, while the posterior end of the cerebrum moves rapidly toward the occipital pole. After birth the posterior end of the insula is fixed, while the anterior end, as growth advances, oscillates slightly—at first approaching and then retreating from the anterior end of the cerebrum.

"8. An anterior limb of the Sylvian fissures can be determined only by the following tests: (*a*) it must cut right through the entire thickness of the operculum and reach the furrow surrounding the island of Reil; (*b*) it must lie in front of the precentral sulcus.

"9. A single anterior limb of the Sylvian was present in 30 per cent. of the hemispheres examined; the two anterior limbs, quite distinct and separate, were present in 37.5 per cent.; the **Y**-shaped condition of the two limbs was present in 31.5 per cent.

"10. The two orbital limbs of the Sylvian fissure cannot be regarded as belonging to the same category of the true anterior limbs. They are not developed as primitive deficiencies in the orbital operculum.

"11. The posterior insula is not connected with the extremity of the temporal lobe, as Erbstaller has asserted, but with the limbic lobe.

"12. On the surface of the fœtal insula there appear three radial furrows which correspond in every respect with the three 'Primärfurchen' on the outer surface of the mantle (viz., the fissure of Rolando, the inferior precentral sulcus, and the vertical limb of the intraparietal sulcus). The radial furrows on the insula clearly belong to the same fissural system and intermediate links between the three radial fissures on the outer surface of the hemisphere, and the three radial fissures on the insula may exist in the form of secondary sulci, cutting the margin of the fronto-parietal operculum.

"13. The fissure of Rolando is clearly the proper boundary of the frontal lobe. Above, it is separated only from the calloso-marginal fissure, which bounds the lobe internally, by a narrow but superficial gyrus; below, the inferior transverse furrow of Erbstaller acts as an intermediate link between it and the sulcus centralis insulæ. The sulcus centralis insulæ and the calloso-marginal sulcus are brought into close relationship at the anterior perforated spot on the base of the brain. An almost continuous fissural system, therefore, marks out the limits of the frontal portion of the cerebrum.

"14. The temporal pole is formed entirely by the forward growth of the fore part of the temporal operculum.

"15. In the adult brain the insula is proportionately longer in the male than in the female. At all periods of growth it would seem that the insula is relatively longer on the left side than on the right side. In the negro brain it would appear that the insula is relatively shorter than in the European brain.

"16. In the anthropoid ape the so-called anterior limb of the Sylvian fissure is not homologous with either of the anterior limbs in man.

"17. In the chimpanzee and orang there are only two opercula, viz., the fronto-parietal and the temporal. The frontal and orbital opercula of the human brain are entirely absent in the anthropoid cerebrum.

"18. Restricting the term insula to that part of the hemisphere surface which is concealed from view by opercula, the extent of this area in the ape is very much less than in man. The central index is 18.2 in the chimpanzee and 21.5 in the orang; in man the central index is 29.6. In the lower apes the central index is higher than in the anthropoids.

"19. In man the field of the insula shows marked changes with reference to the cranial wall during intrauterine life. More and more of its area comes to lie under cover of the parietal bone, and relatively less under cover of the frontal bone, as development proceeds. In the adult the coronal line cuts the insula in such a manner that thirteen per cent. of its length lies in front of it and eighty-seven per cent. behind it.

"20. In the chimpanzee and the low apes no part of the insula lies in front of the coronal line; in the orang the upper and anterior corner of the insula projects slightly in front of this line.

"21. In the human infant and young child, as well as in the ape, the point at which the stem of the Sylvian fissure reaches the outer surface of the hemisphere is situated relatively farther back than in the human adult.

"22. The Sylvian fissure is relatively longer in the left hemisphere than in the right, and in the ape than in man. . . .

"28. In the Cebus (Figs. 853 and 854) the Sylvian fissure lies above the level of the squamous suture; in the macaque, homadryas, and orang, it lies immediately subjacent to the fore part of the suture; in *Cynocephalus anubis* and the chimpanzee the fissure is situated in its fore part below the level of the front part of the suture.

"29. The relative depth of the parietal and temporal lobes in the lower apes resembles that in the human child; in the anthropoid ape the relative parietal depth of the hemisphere exceeds that in the human adult."

The Fissure of Rolando.—Cunningham found that in sixty per cent. of the brains examined the upper end of the fissure of Rolando turned over the mesal border of the hemisphere; in nineteen per cent. its ventral end was connected by a shallow transverse sulcus with the Sylvian fissure. The fissure of Rolando appears in two parts; the lower two-thirds appears before, and independently of, the upper third. The relative position of the fissure of Rolando is remarkably constant. The upper fronto-Rolandic index is 53.3, the lower 43.3. In anthropoids the upper end of the fissure of Rolando is placed relatively farther back than in man. The average Rolandic angle in the human brain is 71.7. The average relative length of the fissure of Rolando is 39.3.

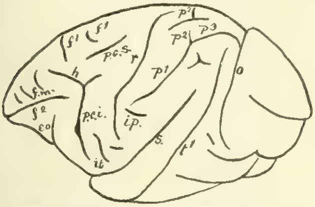


FIG. 852. Left Cerebral Hemisphere of a Chacma Baboon. *p*, Various parts of the intraparietal system of furrows; p^1, sulcus postcentralis inferior; p^2, two parts of the sulcus postcentralis superior; p^3, ramus horizontalis; *i.p.*, sulcus postcentralis transversus; *o*, occipital operculum.

The Intraparietal Sulcus.—"1. The entire sulcus, single and continuous in some of the lower apes (*e.g.*, Cebus), becomes broken up in the human brain into a group of furrows which present different relations to each other in different cases.

"2. Three of the elements of the sulcus in the human brain, viz., the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis, are disrupted portions of the original fissure; one, the sulcus postcentralis superior, is a superadded element (Fig. 859).

"3. In the development of the sulcus in the human fœtal brain, all the four segments of the sulcus have, as a rule, an independent origin, although, as Pansch has shown, the sulcus postcentralis inferior and the sulcus horizontalis very frequently appear as one continuous furrow.

"4. The sulcus postcentralis inferior usually appears first; then the ramus horizontalis and ramus occipitalis; and last of all the sulcus postcentralis superior.

"5. In Cebus there is no sulcus postcentralis superior; it is present, however, in most of the old-world apes, *e.g.*, the baboon, macaque, gibbon, chimpanzee, orang, and gorilla (Fig. 858).

"6. In the chimpanzee and orang there is reason to believe that this segment of the postcentral sulcus consists of two elements, one placed above the other (Figs. 856 and 857).

"7. Eberstaller's third and lower segment of the postcentral sulcus (viz., the sulcus postcentralis transversus) is not only present in man, but also in the majority of the old-world apes.

"8. In the apes the intraparietal sulcus is deeper than the fissure of Rolando; the opposite is the case in man. This would seem to indicate that the morphological value of the sulci is different in man and the apes. The phylogeny and ontogeny of these furrows are in apparent variance with each other. The fissure of Rolando appears first on the developing cerebrum of the human fœtus, yet it is the intraparietal sulcus which first makes its appearance in the evolution of the primate cerebrum. . . .

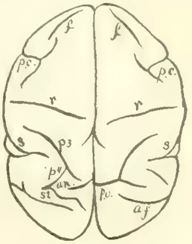


FIG. 853.—Cerebrum of Cebus Albifrons. *f*, Sulcus frontalis inferior; *p.c.*, sulcus postcentralis inferior; *r*, fissure of Rolando; *s*, Sylvian fissure; *p*, intraparietal sulcus; p^3, ramus horizontalis; p^4, ramus occipitalis; *st*, furrow corresponding to sulcus transversus occipitalis of Ecker; *p.o.*, parieto-occipital fissure; *an.*, first annectant gyrus; *a.f.*, ape cleft.

"11. In man there appears to be a general tendency toward a union of the two originally distinct postcentral elements of the sulcus, and a divorce from the lower of those of the ramus horizontalis. . . .

"13. The ramus occipitalis was connected with the ramus horizontalis in 63.7 per cent. of the adult human hemispheres examined.

"14. The union between these two elements of the sulcus, as Ecker and Wilder have shown, is much more common on the left side than on the right.

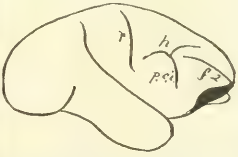


FIG. 854.—The Outer Surface of the Cerebrum of Cebus Albifrons. *r*, Fissure of Rolando; *p.c.i.*, sulcus præcentralis inferior; *h*, ramus horizontalis; f^2, inferior frontal sulcus.

"The sulcus transversus of Ecker is not the homologue of the 'Affenspalte' in the apes, but merely a terminal bifurcation of the ramus occipitalis."

The Sulcus Præcentralis.—"1. The sulcus præcentralis inferior in the human brain is composed of a vertical and a horizontal limb. The latter is carried forward into the middle of the frontal convolution.

"2. This furrow is the earliest to appear on the outer surface of the frontal lobe of the fœtal brain. In some cases it is seen in the fifth-month cerebrum in the form of a long, deep, vertical sulcus, which subsequently undergoes a retrograde development before its adult condition is reached. In many cases, in its early condition, it presents a form in every respect comparable with that ob-

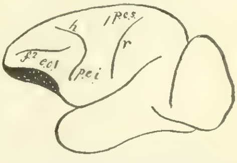


FIG. 855.—Another View of the Same. *p.c.s.*, Sulcus præcentralis inferior (?); *e.o.*, a slight trace of the sulcus fronto-orbitalis. Other letters as in Fig. 854.

served in the cerebrum of the low ape (Cebus). Frequently it is developed in several pieces.

"3. The sulcus præcentralis superior is closely connected with the basal part of the first frontal furrow. It is usually developed along with it. It consists of two pieces—an upper and a lower—which may be partially or completely separated from each other, as well as from the basal part of the first frontal furrow by an annectant gyrus.

"4. Two additional furrows belonging to the precentral system are occasionally present, viz., the sulcus præcentralis medius and the sulcus præcentralis marginalis.

"5. The sulcus præcentralis medius may arise in two different ways: (*a*) It may be formed by the ramus horizontalis of the inferior precentral sulcus divorced from the vertical stem and assuming a very oblique or an almost vertical position; (*b*) it may consist of a new element placed between the superior and inferior precentral furrows, but showing a closer connection with the former. . . .

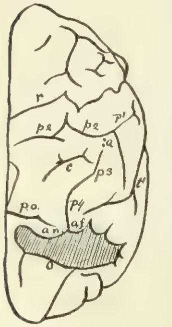


FIG. 856.—Cerebral Hemisphere of Young Female Chimpanzee, as seen from above. The operculum on each side has been removed. *r*, Fissure of Rolando; p^1, sulcus postcentralis inferior; p^2, two portions of sulcus postcentralis superior; p^3, ramus horizontalis; p^4, ramus occipitalis; *b*, terminal bifurcation of the intraparietal sulcus; *p.o.*, parieto-occipital fissure; *a.n.*, first parieto-occipital annectant gyrus; *a*, deep annectant gyrus in the course of the intraparietal sulcus; *c*, secondary sulcus in the superior parietal lobule; *a.f.*, bottom of the "ape-cleft"; *o*, cut surface of occipital operculum; t^1, parallel sulcus.

"12. The superior frontal gyrus and the middle frontal gyrus are each partially subdivided into two tiers or subdivisions by furrows which may be respectively termed the sulcus frontalis mesialis and the sulcus frontalis medius.

"13. Both of these furrows have secured a firm footing in the human brain, but only one (viz., the frontalis medius) has established itself upon the brain of the chimpanzee (Fig. 856). . . .

"17. The sulcus frontalis mesialis is absent or poorly developed in the brain of the negro. . . .

"20. The sulcus præcentralis inferior and the inferior frontal sulcus are the furrows which are most firmly impressed upon the brain of the apes. In Cebus they alone are present; in Calithrix there are also traces of the sulcus præcentralis superior and sulcus fronto-orbitalis; in the baboon there are, in addition, a rudimentary sulcus frontalis superior, and perhaps (?) traces of a sulcus frontalis medius (Figs. 852 and 853).

"21. In the chimpanzee and the gorilla the sulcus frontalis medius is often present in a form precisely similar to that seen in the human brain; in the orang the condition of this sulcus is doubtful; in the gibbon the sulcus frontalis medius is absent.

"22. In the chimpanzee, therefore, the same convolution ties may be seen as in man, with this exception: the superior frontalis is never split into two by a sulcus frontalis mesialis.

"23. The inferior frontal convolution of apes is very different from that in man.

"24. The frontal and orbital Sylvian opercula are completely absent in the apes.

"25. Consequently, a portion of the island of Reil is uncovered and exposed on the surface of the cerebrum.

"26. The sulcus fronto-orbitalis of apes corresponds to the anterior limiting sulcus of the island of Reil in man.

"27. There are no anterior limbs of the Sylvian fissure in the anthropoid apes. The so-called anterior limb of the Sylvian fissure corresponds to the anterior free border of the fronto-parietal operculum.

"28. About the seventh month of fœtal life the inferior precentral sulcus of the human brain attains a position which it retains unaltered throughout all the subsequent changes of growth; previous to this it is placed relatively farther back on the surface of the hemisphere.

"29. At first it is placed in front of the coronal suture. The sutural line, however, moves forward so that the sulcus ultimately comes to lie behind it.

"30. In the ape cerebrum the inferior precentral sulcus lies relatively much farther forward than in the cerebrum of man. It may be placed subjacent to, or in front of, the coronal line."

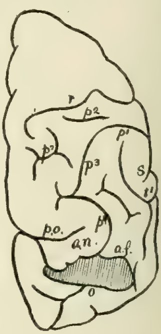


FIG. 857.—Right Hemisphere of a Male Orang, Six Years Old. *r*, Fissure of Rolando; p^1, sulcus postcentralis inferior; p^2, two parts of sulcus postcentralis superior; p^3, ramus horizontalis; p^4, ramus occipitalis; *a.n.*, first parieto-occipital annectant gyrus; *p.o.*, parieto-occipital fissure; *a.f.*, bottom of "ape-cleft"; *o*, cut surface of occipital operculum; *s*, fissure of Sylvius; t^1, parallel sulcus.

The Hippocampus. — The median part of the mantle, that portion which adjoins the opposite hemisphere and the thalamus, is very early separated from the rest of the cortex by a total fissure consisting of the hippocampal fissure, the fissura calcarina, and the (temporary) fissura parieto-occipitalis. The portion so separated is the gyrus marginalis, and from it there develops caudally the curious structure known as the hippocampus or Ammonshorn. The hippocampus is enrolled like a scroll and its mesal margin is rolled by an inverse curve into the space left by the loosely rolled fornicate portion. This portion of the cortex has been shown to be related to the function of smell, and to it are traced various bundles from the olfactory tuber. From it also rise fibres which cross in the hippocampal commissure or decussate in the fornix body and thence descend by the columns of the fornix to the thalamus. Some of the fibres pass to the tuber cinereum and enter the mammillary bodies.

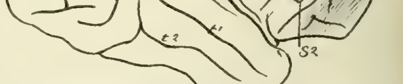


FIG. 858.—Right Cerebral Hemisphere of a Male Orangoutang, Six Years Old. f^1, Sulcus frontalis superior; f^2, sulcus frontalis inferior; *f.m.*, sulcus frontalis medius; *c.o.*, sulcus fronto-orbitalis; *p.c.*, sulcus præcentralis inferior; *p.c.s.*, sulcus præcentralis superior; *p.c.i.*, sulcus præcentralis inferior; *r*, fissure of Rolando; p^1, sulcus postcentralis inferior; p^2, sulcus postcentralis superior; p^3, sulcus horizontalis intraparietalis; *e.c.*, external calcarine fissure; t^1, parallel sulcus; t^2, second temporal sulcus; H^1, H^2, H^3, transverse temporal gyri of Heschl; *R*, insula; A^1, first annectant gyrus; S^2, anterior free border of the fronto-parietal operculum; *O*, anterior edge of the occipital operculum.

The Olfactory Region.—From a part of the hemispheres near the cephalic end of the gyrus marginalis, in lower animals at the cephalic extremity of the brain, while in higher mammals the point is ventrally folded, there arises a protuberance called the olfactory lobe. Still cephalad the ventricle is produced to form a dilatation of the wall—the olfactory tuber. The actual means by which the tuber is formed may be discovered by watching the early stages of development. At a very early period the front of the hemispheres comes into actual contact with the depressions of the skin forming the olfactory fossa (Figs. 863 and 864). In this fossa there develop the ganglion cells of the olfactory from the proximal end of which the olfactory fibres make their way into the hemispheres. In this way the hemispheres are connected with the epithelium and the connection is retained from this time on. In some cases, as in certain fishes, the growth of the head causes the brain to be withdrawn a long distance from the olfactory fossæ, and the tuber is drawn out into an almost thread-like stalk which has often been mistaken for the olfactory nerve. In other cases the tuber has refused to be separated from the brain, and the fibres connecting with the olfactory epithelium have been extended and have been usually called the olfactory nerve, though here again incorrectly, for in a strict sense there is no olfactory nerve and this bundle should be called the root. In the tuber two portions can be distinguished, the unaltered protrusion of the brain called the pes, and a slipper-like enlargement covering the pes, called the pero. In the latter is developed what is known as the glomerule zone, in which the final branches of the olfactory root fibres mingle with the arborizations of the special mitral cells of the pero. Fibres from the latter pass backward to the region of the hippocampus.

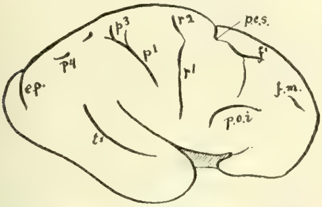


Fig. 859.—Outer Surface of a Cerebral Hemisphere in the Early Part of the Seventh Month. t^1, Parallel sulcus; *p.c.i.*, inferior frontal; f^1, sulcus frontalis primus; *p.c.s.*, sulcus præcentralis superior; *r*, fissure of Rolando; *p*, intraparietal sulcus; p^1, sulcus postcentralis inferior; p^3, ramus horizontalis of the intraparietal sulcus; p^4, ramus occipitalis; *e.p.*, fissura perpendicularis externa.

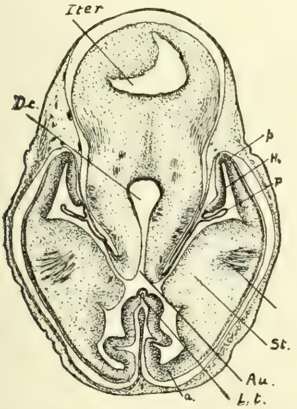


Fig. 860.—Horizontal Section of Guinea-Pig Head. *Dc.*, Diacele; *St.*, striatum; *Au.*, aula; *L.t.*, lamina terminalis; *P.*, plexus; *H.*, hippocampus; *a.* and *p.*, proliferating areas; *x.*, inner capsule.

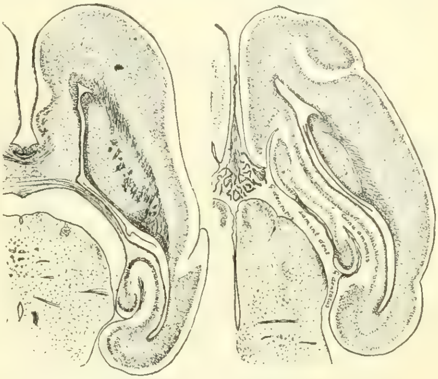


Fig. 861.—Two Horizontal Sections of Brain of Young Opossum, to Show Hippocampus and Fimbria.

The Diencephalon and Mesencephalon—The external characters of the thalamus have already been mentioned in sufficient detail. Within there develop a number of clusters of cells which are better known in lower animals than in man, but in all cases the exact function remains problematical. It seems certain that the several tracts from organs of special sense here find rendezvous and from these temporary stations extend to the cortical areas. From the cerebellum fibres enter the nucleus ruber. From the geniculate nuclei the optic radiations pass to the occipital cortex. The rapid growth of the roof of the mesencephalon, as well as the curvature of the base due to the midbrain flexure, tends to fill the midbrain vesicle, and in mammals the narrow iter alone re-

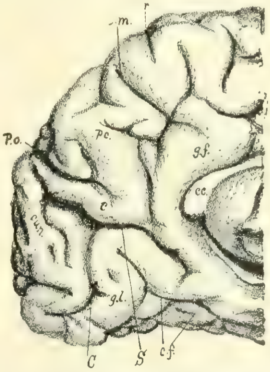
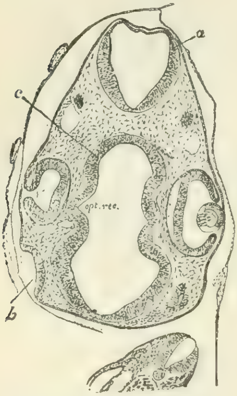


Fig. 862.—Hinder Portion of Cerebral Hemisphere of Full-Term Fœtus, Showing Conditions Approximating to Those of Anthropoid Apes. *r*, Upper end of fissure of Rolando; *c.m.*, calloso-marginal sulcus; *p.o.*, parieto-occipital fissure; *cun.*, cuneus; *c*, gyrus cunei; *p.c.*, præcuneus; *g.f.*, gyrus fornicatus; *c.c.*, callosum; *c.f.*, collateral fissure; *C*, posterior secondary calcarine fissure; *S*, "stem" of calcarine fissure.

mains. The basal or pes portion develops the several centres for visual co-ordination, while the dorsal longitudinal fasciculus lies immediately beneath the iter. Ventrally the fibres passing in both directions connecting the prosencephalon with the medulla oblongata form a thick mass on the external aspect of the pes, called the crusta, through which the fibres of the third nerve find exit.



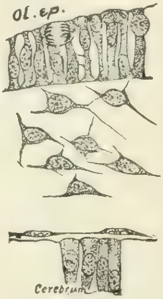


FIG. 863.—Section through Head of Garter-Snake Embryo. *a*, Midbrain; *b*, olfactory pit; *c*, infundibulum.

FIG. 864.—Epithelium of Olfactory Pit in Proliferation.

The Medulla Oblongata and the Cerebellum.—Reference has already been made to the relation of the cerebellum to the medulla, and also to the fact that this massive organ is built up partly from proliferations from the lateral walls of the fourth ventricle and partly from the concrescence of masses proliferated at the cephalic margin of the tela. In some mammals, at least, the writer has described a process of actual eversion of a sac from the lateral walls of the fourth ventricle in the region of the future cornucopia to give rise to superficial proliferating areas to supply the surface when cut off from the direct replenishment from the ventricles by the intrusion of the white matter. (*Cf.* Figs. 865–868.) In an entirely similar way Professor His explains the origin of the olives by the eversion of the walls of the fourth ventricle at a lower level and the final envelopment of the proliferating epithelium in the parietes of the medulla.

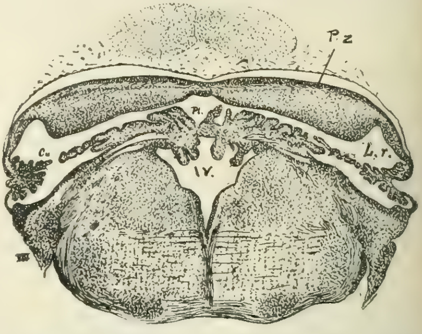


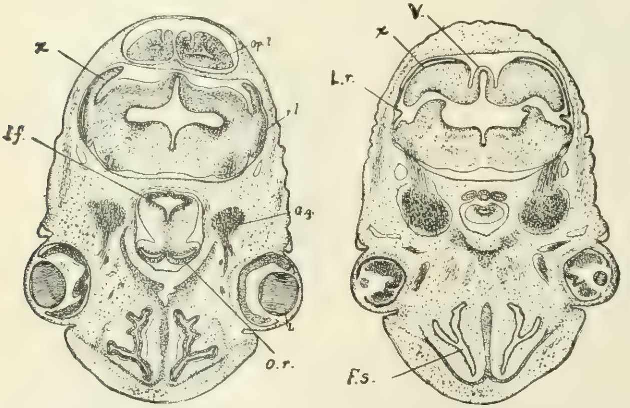
FIG. 867.—Transverse Section of the Medulla and Cerebellum of Mouse Embryo. *P.z.*, Superficial proliferating zone derived from the epithelium of everted lateral recess; *L.r.*, lateral recess; *Pl.*, plexus; *c.*, cornucopia; *VIII.*, root of eighth nerve; *IV.*, fourth ventricle.

The margin of the cellular portion of the roof of the fourth ventricle constitutes the rhomboidal lip ("Rautenlippe" of His), which has been shown by many independent observers to have a most important function as a proliferating organ for both the medulla and the cerebellum.

In man there is a greater development of nervous matter in the roof of the fourth ventricle and the walls of the lateral recess than in lower mammals. In all mammals there is a caudal as well as two lateral protrusions of the membranous walls (tela). The lateral protrusions form the lateral recesses just mentioned, while the caudal projection in man becomes perforate, forming the foramen of Magendie or metapore. This pore is characteristic of anthropoids, but is absent in lower mammals.

Even as early as the end of the third week the forebrain forms almost a right angle with the medulla, and during the fourth and fifth weeks the pons flexure increases till the base of the mesencephalon is separated from that of the medulla only by the narrow and deep "saddle cleft." From the dorsal extremity of this cleft arises the fossa Tarini. The pons flexure gives opportunity for the development of the cerebellum by providing a place for it. The flexure finds reciprocal expression in the choroid fold or inward loop of the tela.

The cerebellum is divided into a median vermis, and, on either side, a pileum, paraflocculus, and flocculus. The regions which form the pilea are first developed and the vermis is last to appear. The first sulci also appear on the lateral parts and not on the



FIGS. 865 AND 866.—Horizontal Sections through the Head of Embryo Guinea-Pig. (Compare also Fig. 860 from the same series farther dorsad.) Fig. 865 passes through the level of the eyes and infundibulum. The extension of the ventricle of the optic recess into the stalks of the optic nerves is shown at *O.r.* *G.g.*, Gasser's ganglion; *L.*, lens; *Op.l.*, optic lobes, roof of mesencephalon; *r.l.*, lateral recess of fourth ventricle extending upward within a fold of the rhomboidal lip to cover the lateral aspects of the cerebellum, as at *x*. Fig. 866 passes at a somewhat lower level, and shows the extension of the lateral recess near the tip of the cerebellum. At *L.r.* the beginning of the cornucopiæ is shown; *F.s.*, frontal sinuses.

vermis. At about the middle of the third month four or five transverse convolutions appear on the vermis. By the fifth month the definitive form of the cerebellum is clearly defined. By this time the prepeduncles connect with the midbrain, and the valvula is formed by the thinning of the dorsal walls cephalad of the vermis. As early as the third month the restiform bodies connect with the lateral lobes to form the postpedunculi. In the fourth month the medipedunculus and pons become obvious.

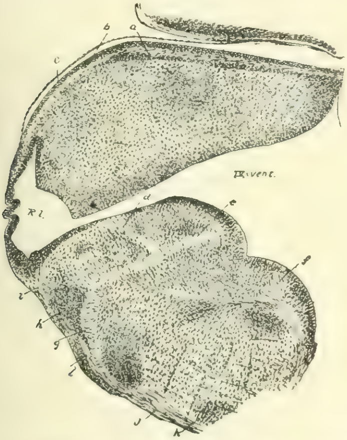


FIG. 868.—Portion of Similar Section to Show the Double Proliferating Zone with Fibre Layer Between, at *a*, *b*, *c*.

The formation of the pons by the decussating fibres of the medipeduncle of the cerebellum greatly modifies the cephalic part of the organ and leaves an isthmus region between the cephalic border of the pons and the mesencephalon which otherwise would perhaps hardly rise to the value of a recognized portion of the brain. At different levels in the medulla the sensory and the motor bundles connecting the cord with the upper parts of the brain decussate, and by this means the simplicity of structure seen in the cord is entirely destroyed in the myelencephalon. Added to this is the remarkable differentiation of the centres of the several cranial nerves (*q. v.*), which also obscures the original uniformity of arrangement. The effect of the increased emphasis laid upon a particular sense is well illustrated in fishes, in which, for example, huge excrescences arise on the medulla in the region of one or other of the cranial roots, almost equal to the cerebellum in size.

Several authors have observed even in human brains serially arranged eminences in the floor of the fourth ventricle, but whether they indicate neuromeres in the sense in which that term is now used in morphology, and what their fate may be in the adult, remain points of dispute. At the end of the second month there may be recognized in sections of the medulla four somewhat distinct regions: (1) the region of the motor nuclei; (2) the substantia reticularis; (3) the region of the lateral nuclei and the substantia gelatinosa, and (4) the region of the olives. To these in later stages are added a vast number of tracts and scattered nuclei which may best be studied in the adult brain.

The various regions of the brain developed in the manner above described have been given a great variety of names, and there has as yet been no general agreement as to the connotation of many names in common use. The system proposed by Professor His is given below because of its completeness, though it will require to be modified in detail to adapt it to more general usage.

I.	Medulla oblongata, Myelencephalon I.			Rhombencephalon I. III.	Encephalon.
II_1.	Pons	Metencephalon II.			
II_2.	Cerebellum				
III.	Isthmus rhombencephali III.				
IV_1.	Pedunculi cerebri	Mesencephalon IV.			
IV_2.	Corpora quadrigemina				
V_1.	Pars mamillaris hypothalami		Diencephalon V.	Prosencephalon	
V_2.	Thalamus	Thalamencephalon			
V_3.	Metathalamus				
V_4.	Epithalamus				
VI_1.	Pars optica hypothalami		Telencephalon VI.		
VI_2.	Corpus striatum	Hemisphaerium			
VI_3.	Rhinencephalon				
VI_4.	Pallium				

The term epencepahalon is often applied to the cerebellum, but, in spite of its great size in man, it is only an extension of the lateral walls of the medulla. It has been proposed to use oblongata as the brief substitute for the full form, "medulla oblongata," but the substantive seems the more natural part of the binomial, as the objection that medulla is ambiguous is of no practical moment.

Prosencephalon has been generally used as synonymous with telencephalon as applied by His, and by using metencephalon instead of rhombencephalon we have a series of terms, founded on a sound embryological basis, which may be considered correlative and which are easily applied, viz., meten-, mesen-, dien-, and prosen-cephalon.

Closely related to the prenatal changes above described are their postnatal consequences. There is no sharp line to be drawn between the phenomena of growth before birth and those which continue in after life. Changes in proportion during the adolescent period affect the relation between head and body and between brain and the remainder of the central nervous system. Brain development proceeds in advance of that of the body at large, though in cases of defective development of the brain the body may attain a considerable degree of perfection, as has been shown by Lenowa. In a fœtus of twenty-one weeks, according to Bischoff, the percentage weight of the brain to body is 18.5, in new-born male children 15.8, in new-born female children 12.2, at sixteen years of age the percentage is 3.9, in adult males it is 1.9, and in adult females 2.1. At birth the weight is nearly alike in the two sexes, but the absolute weight is, of course, influenced by the size of the body. During the first year, and to a somewhat less extent for the three following years, the growth is very rapid. By the seventh year the encephalon has nearly attained its full weight. After about the fiftieth year a gradual loss of weight becomes apparent.

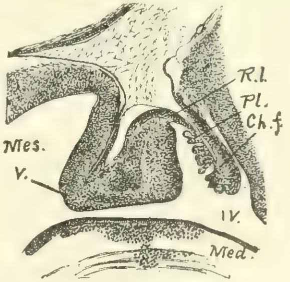


FIG. 869.—Longitudinal Section of Cerebellum of Early Mouse Embryo. *Mes.*, Mesocele or iter; *V.*, valvula; *R.l.*, rhomboidal lip, and proliferating area derived from it; *Pl.*, plexus; *Ch.f.*, choroideal fold; *IV.*, fourth ventricle; *Med.*, medulla base.

The continuous and unequal demands made upon various parts of the brain operate to stimulate growth, waste, and repair to an unequal degree in different parts. In this connection it is important to note that there are laid up in store in certain parts of the brain nascent or latent cells (granules) which may interpolate themselves among the depleted cells of older growth.

Education in its broadest sense includes all changes in the brain due to reactions of the organ upon afferent stimuli. It is usual to state that all the elements (cells, etc.) of the brain are preformed in it at birth. If this were so, then education would consist in the progressive modification of these cells and the perfection of a wide range of intercommunications between them. Leaving out of the account the possibility of the proliferation of new cells from a germinative epithelium, there can be no doubt that the latent cells above mentioned are called into activity by exercise, and increased brain power and a more extended range of activity are thereby secured. It would apparently follow that activity of mind would hasten the period of senility and brain decline; but as the reverse is the case, it may be assumed that proliferation or an analogous process really takes place.

C. L. Herrick.

BRAIN DISEASES: DIAGNOSIS OF LOCAL LESIONS.—History.—Although it was known in the first century that each hemisphere of the brain is in functional relation with the opposite half of the body, the facts upon which the prevailing theory of the localization of different functions in separate parts is based were not discovered until 1822. At that time Thomas Hood, in England, and Bouillaud, in France, noticed that disturbances of speech were caused by disease in the frontal lobes of the brain. M. Dax (1836) was the first to limit the area governing speech to the left frontal lobe, and Broca (1861) located it more exactly in the left third frontal convolution. The discussion of aphasia in the Academy of Medicine in Paris in 1864 awakened general interest and led to further investigation. Until that time scientific men, rejecting the unwarrantable conclusions of Gall and the phrenologists, had believed the teachings of Flourens, that the brain acts as a whole, its various parts not possessing various powers. The pathological evidence against this position collected by Broca, and strengthened during 1864–67 by facts observed by Hughlings Jackson and Meynert, received confirmation in 1870 from a new series of physiological experiments made by Fritsch and Hitzig in Berlin. These investigators found that in animals the anterior portion of the convexity of the brain is motor; that its irritation by electricity causes coordinated motions in the limbs of the opposite side, and that its destruction causes paralysis. Ferrier (1873–76), Nothnagel (1877), Munk (1881), and Luciani (1884) have confirmed these results, and have shown further that the posterior portion of the convexity is sensory, its destruction being attended by impairment of the powers of perception through the various senses. Goltz, though opposing a strict limitation of functions to definite regions, admits that the results of destruction of various parts are different, and he has noticed that extensive injury to the anterior portion changes the character of an animal from kind to vicious, while injury to the posterior portion has the opposite effect. The conclusions of physiologists differ regarding the results of experiments, but do not overthrow the theory of localization as applied to man; for a mass of pathological evidence has been collected during the past ten years which will bear but one interpretation. Charcot and his pupils in France, Nothnagel, Exner, and Wernicke in Germany, H. Jackson and Ferrier in England, and others, have gathered, classified, and analyzed a very large number of cases of brain disease of limited extent, which were accompanied by definite symptoms, and have established a causal relation between lesions of certain portions of the brain and disturbances of certain functions, both motor and sensory. It has also been discovered that deficient development of an organ is accompanied by deficient development of that part of the brain which is in functional relation with that organ, and *vice versa* (von Gudden).

Further, the researches of Flechsig (1877–84) have proven that an anatomical connection exists between certain organs and certain parts of the brain by means of tracts, which can be distinguished from one another by peculiarities in the time and process of their development. To these same tracts are limited the secondary changes which ensue when the active organ at one extremity of the tract is destroyed.

All these various kinds of evidence combine to establish the conclusion that definite parts of the brain possess distinct functions, and although there remain numerous functions whose location is unknown, and many parts of the brain whose function is undetermined, a sufficient number of facts is available to warrant in many cases of cerebral disease a localization of the lesion.

General Considerations.—Since the different parts of the brain preside over different functions, the symptoms present in any lesion will depend as much upon its situation as upon its nature. Certain general symptoms, such as headache, vertigo, convulsions, coma, or optic neuritis, occur in many forms of disease, and being indications of disturbances of nutrition, or of increased intracranial pressure, do not indicate the position of the disease. Other symptoms, however, such as disturbances of motion, of sensation, of sensory perception, of memory, or of speech, are known as local symptoms, since each is present only when a certain part of the brain is involved. It is from these that the localization of a lesion can be determined. Local symptoms must, however, be interpreted with caution, and the direct effect of the lesion must be distinguished from its indirect effect. For example, immediately after a cerebral hemorrhage, attended with headache, vertigo, or coma, and possibly general convulsions and vomiting, the local symptoms of hemiplegia, hemianæsthesia, and aphasia may be present, and may lead to the suspicion of a very extensive lesion. After a few days, however, there may remain only a partial hemiplegia, all other symptoms having subsided. In such a case the hemiplegia is the only direct local symptom; the indirect local symptoms—aphasia and hemianæsthesia—being incidental to the pressure on, or to disturbance of, circulation in parts adjacent to the actual seat of disease. It is only when a lesion is single, its effects stationary and of some duration, that a diagnosis of its position is to be made.

In diagnosticating the position of a lesion it is necessary to distinguish disease in the cortex from disease within the hemisphere. The functions of these parts are different. The gray cortex receives and initiates impulses. The white matter within the hemisphere transmits the impulses. The impulses sent along white tracts to the cortex become conscious perceptions only when they reach their destination in the gray matter. The impulses passing along the white tracts from the cortex have been started in the gray matter as conscious volitions by effort. Thus sensation or motion may be suspended either by disease in the cortex or by disease in the tracts within the hemisphere. The cortex has another function. A sensation once perceived, or a motion once acquired, leaves behind it a trace, whose nature is unknown, which shows itself in a disposition in the cells of the cortex to react more promptly to a similar impulse than to a dissimilar one. This is the physical basis of memory. Since similar impulses always enter by the same sensory organ, and since each organ is connected with its own region of the cortex, it follows that the various memories are distributed in various regions. But these memories are often associated in consciousness, and this association is secured by means of white fibres which pass between and connect the various regions. It becomes evident, therefore, that diseases of memory may afford an important clue to the location of a lesion; and that the distinction between a disease of the gray cortex involving a loss of a certain kind of memory, and one of the white tracts within the hemisphere interfering with the proper association of ideas must not be overlooked. No part of the gray matter can act vicariously for another part. Each tract conveys its own impulses.

Diagnosis.—I. Cortex Cerebri.—1. Lesions involving the frontal lobes upon the base may destroy the olfactory bulb or tract and produce anosmia on the side of the lesion. Lesions in the other convolutions of the frontal lobes, excepting those in the posterior part of the third convolution of the left side, present no distinctive local symptoms. Some disturbance of mental action, manifested by an inability to concentrate the attention, to think connectedly, and to control the emotions, or even by a condition of imbecility, may be caused by disease in this region.

These convolutions are often defective in idiots, and their comparative development in animals determines the mental power of the individual. But disease in this region in man does not cause a loss of any particular mental faculty, and for the higher powers of mind no location can be determined. Normal mental action implies the integrity of the entire brain. When general symptoms of cerebral disease are present, but no local symptoms can be found, the possibility of disease in the frontal convolutions is to be considered, and the occurrence of the mental disturbance mentioned affords a presumption in favor of this location.

Lesions in the posterior part of the third frontal convolution on the left side in right-handed, and on the right side in left-handed persons give rise to ataxic or motor aphasia (Fig. 870). In this area are located the memories of the combination of motor acts necessary to the pronunciation of words, memories which have been acquired by practice. If these memories are blotted out, the ability to initiate the impulse required to produce a given sound is lost, and speechlessness results. When this convolution alone is affected the patient can understand what is said to him, and may be able to write, but cannot talk (see *Aphasia*).

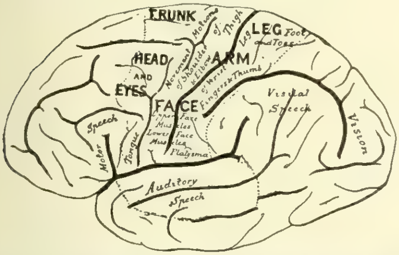


FIG. 870.—Diagram of the Fissures and Convolutions of the Convexity of the Left Hemisphere of the Brain, with the areas presiding over various functions. The speech areas are shown on this hemisphere. The motor area is more extensive on the left than on the right hemisphere.

2. Lesions of the anterior and posterior central convolutions and of the paracentral lobule produce disturbances of motion (Fig. 870). The motor tracts which connect these convolutions of each hemisphere with the body decussate partially in the medulla, and the degree of the decussation differs in different individuals. In the large majority of persons the tracts which cross to the opposite side are so much larger than those which go to the same side that the symptoms of cerebral disease are noticed only on the side of the body opposite to the side of the lesion. In all cases, however, except in those in which the decussation is complete (one in sixty), the side which is apparently normal is slightly affected. The disturbances of motion may be in the form of spasms and convulsions, or in the form of paralysis. Lesions irritating the motor region give rise to the former; those which destroy the cortex to the latter. The lower third of the anterior central convolution is in functional relation with the muscles of the face and tongue (Fig. 870). The middle third of both central convolutions governs the arm (Fig. 870), the motions of the shoulder, elbow, and hand lying from before backward and from above downward in the order named. The upper portion of both convolutions and the paracentral lobules contain the motor centres for the body and leg, the motions of the hip, knee, and foot lying from before backward and from above downward in the order named. The area related to the movement of the eyes is located by Landouzy and Exner in the inferior parietal lobule. As these areas for each part are distinct, cortical lesions of limited extent may affect one alone, or two adjacent areas; but it is only lesions of very great extent which can destroy them all. Monospasms, or monoplegia, are, therefore, prominent symptoms in disease of the motor region. An irritation beginning in one area may extend to adjacent areas, in which case a convulsion may commence in one part and then involve other parts. The relative position of the areas, then, determines the order of progress of the convulsion, face, arm, and leg being successively affected, or *vice versa;* and face and leg never being involved together without affection of the arm. When the entire side is involved the convulsion may become general. The seat of the initial irritation may, therefore, be indicated by the order in which the spasms extend. After such a spasm there remains a paresis in the muscles affected, those last and least involved recovering first (see *Epilepsy*). If the irritating lesion becomes a destroying lesion the monospasm is succeeded by monoplegia, and from the part of the body affected the area in the motor region which is destroyed can be determined. In cortical disease it is seldom that the lesion involves a single area without encroaching upon adjacent areas; hence, associated monoplegiæ of face and arm, or arm and leg, are more frequently met with than paralysis of one part alone. But even in these cases the disturbance of motion usually begins or is more marked in one part, rather than in both equally, and the order of extent of paralysis may indicate the direction in which the disease is progressing, and the place from which it started.

In paralysis from cortical lesion there is a loss or marked impairment of the muscular sense, and there may be some disturbance of general sensation. A loss of motor memories, *e.g.*, the motions involved in writing, playing an instrument, using a tool, occurs in cortical disease, and may indicate that the seat of the lesion is in the area of the arm. The limits of the region receiving impulses which awaken the perception of touch, temperature, and pain are not fully determined. It is thought, however, that the motor and sensory regions coincide, while it is probable that the sensory region extends beyond the motor and includes the parietal lobules which lie posterior to the motor area. Ferrier, however, teaches that the gyrus hippocampus is the region in which these sensations are received. Lesions affecting the posterior central convolution give rise to combined motor and sensory symptoms, the sensory areas lying in the same order as the motor areas, face, arm, and leg in the lower, middle, and upper thirds respectively. Lesions in the motor area anterior to the fissure of Rolando usually produce paralysis without anæsthesia. Lesions in the parietal lobules may produce anæsthesia but do not cause paralysis.

Each sensory area is in functional relation with the opposite limb to a much greater degree than with the limb of the same side. Monoanæsthesia may therefore occur from cortical lesion. The loss of sensation is rarely total, as it is probable that the decussation of sensory impulses is rarely complete. The degree of impairment of sensation is to be ascertained only by comparison of the affected limb with the other three. If the sensory area is not destroyed but is only irritated, subjective sensations in the limb whose area is affected occur, and such monoparæsthesiæ are valuable indications of cortical lesion, when disease in other parts is excluded.

Monospasm and monoplegia, monoparæsthesia or monoanæsthesia, are therefore the chief symptoms of cortical disease in the sensorimotor area. The two former indicate an affection lying anterior to the parietal lobules. The two latter may occur when these also are involved. No other local symptoms of disease in the parietal lobules are known, the disturbances of speech or of sight which occur occasionally when the supramarginal gyrus is involved being due to a coincident lesion of the tracts passing beneath it.

3. Lesions of the three occipital convolutions and of the cuneus produce disturbances of vision (Fig. 871, D). Each occipital lobe is in anatomical connection with the like-named half of each retina, and hence a lesion of one occipital lobe produces an affection of vision in the opposite half of both visual fields. Irritation of the cortex of this region may cause hallucinations of vision, and if the irritation is in one lobe the subjective sights will appear upon the opposite side of the median line, and will move with the eyes of the patient. Destruction of the cortex will produce bilateral homonymous hemianopsia, *i.e.*, blindness in the opposite half of both eyes, and may also cause a loss of visual memories; the patient will fail to recognize familiar objects, and cannot recall scenes and faces formerly known. If the lesion is in the left occipital lobe near to its junction with the inferior parietal lobule (see Fig. 870), written and printed language also may no longer be recognized, and the patient, therefore, may lose the power of reading while speech remains. It is not yet possible to affirm the functional relation between various parts of the visual area in the occipital convolutions and various parts of the retinal surfaces, although a few cases indicate that such a relation may exist. The relation of the angular gyrus, which lies anterior to the occipital lobe, to vision is undetermined. While it was formerly supposed to be the centre of the visual area by Ferrier, this view has been opposed by German authorities, who hold that the disturbances of vision which have occurred occasionally when it was diseased have been due to a lesion of the visual tract which lies beneath it and which passes to the occipital lobe (see *Hemianopsia*).

4. Lesions of the first and second temporal convolutions produce disturbances of hearing, but whether each lobe is related to the opposite ear alone, or to both ears, is undetermined (Fig. 871, E). Irritation of these convolutions may cause hallucinations of hearing, and destruction of them may cause deafness. If the lesion is upon the left side and involves the first convolution, the symptom produced is word-deafness, or loss of memory of the sound of words, with consequent inability to recognize the meaning of spoken language or to recall the words necessary to speech. This is also known as sensory or amnesic aphasia. It can be distinguished from motor or ataxic aphasia by the inability of the patient to understand what is said to him (see *Aphasia*).

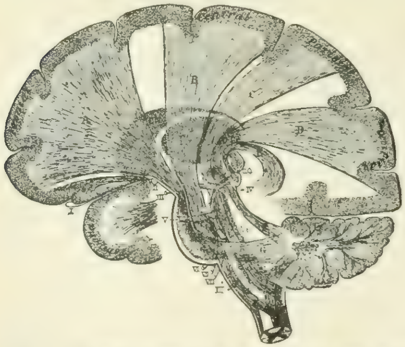


FIG. 871.—The Projection Tracts Joining the Cortex with Lower Nerve Centres. Sagittal section showing the arrangement of tracts in the internal capsule. A, Tract from the frontal lobe to the pons, thence to the cerebellar hemisphere of the opposite side; B, motor tract from the central convolutions to the facial nucleus in the pons and to the spinal cord; its decussation is indicated at K; C, sensory tract from posterior columns of the cord, through the posterior part of the medulla, pons, crus, and capsule to the parietal lobe; D, visual tract from the optic thalamus (O.T.) to the occipital lobe; E, auditory tract from the internal geniculate body (to which a tract passes from the VIII. nerve nucleus [J]) to the temporal lobe; F, superior cerebellar peduncle; G, middle cerebellar peduncle; H, inferior cerebellar peduncle; CN, caudate nucleus; C.Q., corpora quadrigemina; Vt., fourth ventricle. The numerals refer to the cranial nerves.

5. Lesions at the apex of the temporo-sphenoidal lobe may produce disturbances of taste and smell, but further investigations are needed to establish the localization of these functions.

6. Lesions of the island of Reil have caused disturbance of motion in the face and arm of the opposite side, and also have caused aphasia when the left island was involved. It is not certain, however, to what extent these symptoms were dependent upon the affection of adjacent convolutions, of tracts beneath the island, or of the basal ganglia (Figs. 872 and 873). The associating tract which joins the sensory with the motor speech centres lies just under the convolutions of the island of Reil and destruction of this tract would cause paraphasia. Lesions of the island of Reil would be especially liable to affect the circulation in the motor area, since the branches of the middle cerebral arteries pass over it. While, therefore, it can be stated that hemiplegia and aphasia may be produced by lesions here, it is probable that they would be indirect and not direct local symptoms. The function of the island of Reil is unknown.

The facts which have been stated regarding cortical lesions are based upon autopsies and are independent of any physiological considerations regarding the functions of the various parts, although they agree with the results of experiment on animals. It is evident that disease which affects an extensive region of the cortex may produce a number of symptoms arising from the implication of several areas at the same time. Such widespread disease is usually attended by general symptoms, marked mental disturbance, loss of memory, and lack of self-control, as well as by the local symptoms.

II. CEREBRAL TRACTS.—1. The white matter of the brain consists of fibres of two varieties: association fibres which join the different convolutions and functional regions with one another, and projection fibres which join the different convolutions with the basal ganglia and with the gray matter of the pons, medulla oblongata, and spinal cord. These fibres are so interlaced in the centrum ovale that neither can be injured without affecting the other. An interference with the passage of impulses through association fibres produces symptoms of a mental character. An example of this has been cited in describing lesions of the island of Reil, viz., paraphasia. The patient suffering from this disease can recall the desired words, and is able to initiate the motions necessary to speech; but the associating tract between the memory of a definite word and the memory of its motion being broken, he does not speak the desired word but replaces it by another. Thus, in a case known to the writer, whenever the patient spoke she said, "Ah, dear me, I don't know," much to her own annoyance, as she understood what was said to her and knew what she ought to say in reply. The forms of paraphasia are numerous, but are all to be referred to lesion of association fibres. It is very probable that many defects of memory, and much of the apparent stupidity in brain diseases, is to be ascribed to a failure of function in these fibres by which ideas are associated. Nothing more definite can be stated regarding their injury, and the mental symptoms, aside from paraphasia, do not indicate the location of the disease.

2. Lesions of projection fibres produce well-marked local symptoms. It is by means of these fibres that all parts of the body are joined to connecting parts of the brain, so that in imagination a map of the body can be projected upon the cortex of the brain. An interference with any separate bundle of fibres will therefore produce symptoms in the organ with which it is joined, and therefore will cause effects somewhat similar to those produced by a lesion of the corresponding part of the cortex. It is necessary to consider the lesions of the various tracts,

as they produce different symptoms. The projection fibres passing inward and downward from the extensive cortical surface of each hemisphere converge, and are finally collected into a compact tract which lies between the basal ganglia and is known as the internal capsule. Many fibres pass into the basal ganglia, but as their function is only conjectured, the effect of their destruction is unknown. Others pass between the ganglia, through the capsule, and issuing from its basal portion enter the crus cerebri, and traversing it go down to the pons, medulla, and cord.

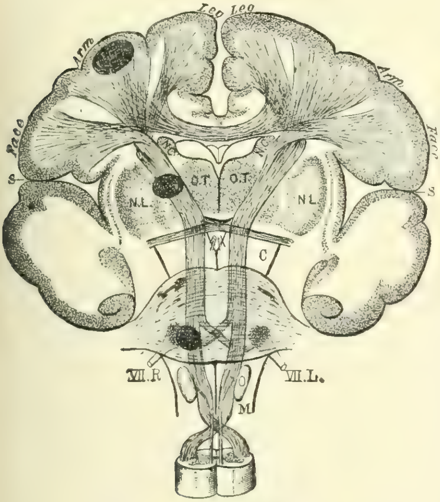


FIG. 872.—The Motor Tract. S, Fissure of Sylvius; N.L., lenticular nucleus; O.T., optic thalamus; N.C., caudate nucleus; C, crus; P, pons; M, medulla; O, olivary body. The tracts for face, arm, and leg gather in the capsule and pass together to the lower pons, where the face fibres cross to the opposite VII. nerve nucleus, while the others pass on to the lower medulla where they partially decussate, to enter the lateral columns of the cord; the non-decussating fibres pass to the anterior median columns. The effect of a lesion situated at three points in the tract is shown on the left side of the figure.

Since the fibres passing through the capsule are gathered from distant and widely separated regions of the cortex, a small focus of disease in the capsule may produce as serious and widespread symptoms as disease of great extent in the cortex. Extensive disease in the cortex, or in the centrum ovale, produces considerable mental impairment, but this is not true of capsular disease. Hence in any case in which the symptoms are extensive, but the mind unimpaired, the probability is in favor of a small lesion in the brain tracts rather than of a large lesion in the cortex. The brain tracts in the capsule may be injured either directly, by lesions in their course, or indirectly, by lesions in the basal ganglia in whose vicinity they pass. In both cases the initial symptoms will be the same if the disease begins suddenly; but in the latter case recovery may follow, while in the former the symptoms may increase in number, owing to secondary degenerations following a lesion of a tract. If the disease is a slowly progressive one (*e.g.*, tumor), general symptoms may precede local symptoms, and indirect local symptoms will be succeeded by direct local symptoms.

The internal capsule is divided into two halves, an anterior and a posterior division, by the projection of the apex of the lenticular nucleus, which lies on its outer side. Through the anterior division pass the projection fibres from the frontal lobes (Fig. 871, A), and the fibres which join the anterior parts of the cortex with the basal ganglia. Nothing is known as to the exact function of either of these bundles of fibres, and no symptoms of their injury can be stated. Extensive lesions may occur in the white matter of the frontal lobes, affecting both association and projection tracts without producing any symptoms, although in many such cases the symptoms present in cortical lesions of the frontal lobes do occur. Through the posterior division of the internal capsule pass several important tracts. These are (1) the motor tract from the lower third of the central convolutions, which curves over the lenticular nucleus and passes down in the anterior part of the posterior division of the capsule, enters the second quarter of the crus, thence passes into the median part of the ventral half of the pons, and turning downward ends in the facial and hypoglossal nuclei (Fig. 874, *Fa.*); (2) the motor tract from the other thirds of the central region (Fig. 871, B), which is known as the pyramidal tract, since its fibres, after passing through the third quarter of the crus and the ventral portion of the pons, make up the pyramid of the medulla (Fig. 874, *M.*); (3) the tract conveying general sensations from the entire body (Figs. 871, C, 874), which lies just behind the pyramidal tract, and having come from the tegmentum of the crus, and passed through the posterior third of the capsule, radiates toward the parietal convolutions (Fig. 874, *S.*); (4) the visual tract (Fig. 874, D), whose fibres, issuing from the pulvinar of the thalamus, pass upward and turn backward in the capsule on their way to the occipital lobe (Fig. 874, *O.*); (5) the auditory tract, which passes through the lower posterior segment of the capsule on its way from the auditory nucleus to the temporal lobe (Fig. 871, E). Lesions of the internal capsule which affect one or more of these tracts cause distinct local symptoms. Lesions in the motor tract produce paralysis, whose distribution will depend upon the extent to which the tract is involved. Usually the entire tract is affected and hemiplegia results; but occasionally the facial and hypoglossal muscles are only slightly affected. In all cases the upper branch of either facial nerve escapes, since its cortical centres are bilateral. In lesions of the pyramidal tract the arm and leg of the opposite side are always paralyzed together. Lesions lying in the sensory tract cause hemianæsthesia, which is rarely absolute, but usually in the form of great impairment of sensation on the opposite side from the lesion. Lesions lying still farther back may affect the visual tract and cause blindness in the opposite half of both eyes. It is possible that lesions in the lower part of the capsule may produce loss of hearing in the opposite ear. Whether taste and smell are ever affected by capsule lesions is undetermined.

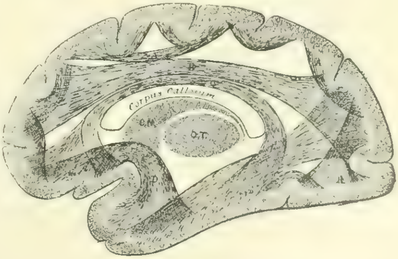


FIG. 873.—The Association Fibres in the Centrum Ovale. A, Between adjacent convolutions; B, between frontal and occipital lobes; C, between frontal and temporal lobes, the cingulum; D, between temporal and frontal lobes—lesion of this tract causes paraphasia; E, between occipital and temporal lobes—lesion of this tract causes word-blindness; C.N., caudate nucleus; O.T., optic thalamus.

It is evident that an extensive lesion in the capsule may involve two or more of these tracts; and hemiplegia, with hemianæsthesia and hemianopsia, could not be produced by a single lesion lying in any other part. The initial effects of a hemorrhage or thrombosis, which involves the internal capsule, may be extensive, as several tracts may be affected. If but one, however, is really destroyed, the affection of the others will be temporary, and the symptoms will decrease in extent and severity until they are limited to the affected tract. It is only after the temporary effects have subsided that the disease can be located accurately. On the other hand, a slowly progressing lesion, tumor, or abscess may involve one tract after another in succession, and the progress of the case will determine the localization of the lesion.

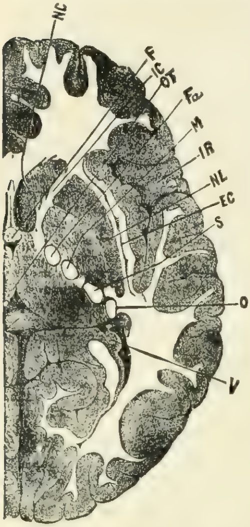


FIG. 874.—Horizontal Section through the Brain. (After Strümpell.) *NC*, nucleus caudatus; *F*, fornix; *IC*, anterior half of internal capsule; *OT*, optic thalamus; *Fa*, facial tract; *M*, motor tract; *S*, sensory tract; *O*, visual tract, in posterior half of internal capsule; *IR*, island of Reil; *NL*, nucleus lenticularis; *EC*, external capsule; *V*, lateral ventricle, posterior cornu.

3. Aphasia may be due to a lesion in the tract which joins the third frontal convolution with the facial and hypoglossal nuclei in the pons. Two courses have been described as taken by this tract. One corresponds to the course of the fibres from the face area of the motor region through the internal capsule, already detailed. The other is as follows: The aphasic tract passes inward from the frontal region, turns backward, crossing at right angles the motor tract, and going along the upper border of the lenticular nucleus, in the external capsule, to its posterior limit, it curves over the nucleus and enters the internal capsule near the sensory tract, then crosses this tract to the second quarter of the crus, and so reaches the pons. Lesions in the course of either of these tracts have produced aphasia when in the left hemisphere. Such an aphasia resembles ataxic or motor aphasia, and is not to be distinguished from it. It is more liable to be associated with agraphia than when the lesion is in the frontal convolution, as association fibres are likely to be destroyed when the lesion is in the centrum ovale.

4. Lesions of the cortex and of the tracts as they are collected in the capsule having been considered, it is evident that lesions of the centrum ovale, through which the tracts pass on their way from one to the other, will produce similar effects to those in either part, according as it lies nearer one or the other. The association fibres which pass through the centrum ovale are shown in Fig. 873. Any interference with them will produce defects in the association of concepts and ideas, and hence be shown by mental defects, especially defects of memory. Lesions of the centrum ovale have no distinctive symptoms by which they can be differentiated from lesions in the cortex or capsule, unless the affection of association fibres as well as of projection fibres adds distinct mental symptoms. If the lesion is so situated as not to affect any of the projection tracts it will not produce any local symptoms.

III. LESIONS OF THE BASAL GANGLIA are very frequent and give rise to many symptoms. These symptoms are, however, to be ascribed to a coincident affection of the tracts just mentioned, which pass through the internal capsule between the ganglia (Figs. 874 and 875), and hence the local symptoms of lesions in the lenticular or caudate nucleus and optic thalamus are those of lesions of the internal capsule opposite those bodies, viz., in its posterior division. If the symptoms are permanent, the capsule is probably injured. If the symptoms pass away, the capsule was incidentally affected. And the effects of the lesion may entirely subside while the lesion remains, if it is limited to either of these ganglia. It is therefore evident that we cannot locate a lesion in the ganglia from any direct local symptoms; for, as we are ignorant of the function of the ganglia, we do not know what is the effect of their destruction. The hemichorea and hemiathetosis which occasionally remain after lesions of the thalamus are to be regarded as symptoms of irritation constantly exerted upon the motor tract passing near it. There are few facts to support the assertions that the optic thalamus is a sensory ganglion, except that lesions of the pulvinar cause hemianopsia. The basal ganglia, doubtless, have important reflex functions, and comparative anatomy indicates that some functional relation exists between the lenticular nucleus and the arm; between the caudate nucleus and the leg; between the thalamus and the organs of sensation. The effects of a lesion limited to any one of these ganglia, and producing no influence upon adjacent parts, are, however, beyond detection. As a matter of fact, seventy per cent. of the cases of hemiplegia are due to a lesion in the basal ganglia and affecting the internal capsule; and from the symptoms and nature of the disease its location there can usually be affirmed. The diagnosis is, however, made from the capsular symptoms, as already detailed.

IV. LESIONS OF THE EXTERNAL CAPSULE AND OF THE CLAUSTRUM cannot yet be located (Figs. 872 and 874). If on the left side, they usually produce paraphasia like the lesions of the island of Reil.

V. LESIONS OF THE CORPORA QUADRIGEMINA are very rare. If the anterior pair is involved, blindness, loss of pupil reflex, strabismus, and nystagmus may be produced. If the posterior pair is involved disturbances of coordination may be marked. As both pairs are usually affected together, the combination of these symptoms may aid a diagnosis. Blindness is such a common symptom of cerebral disease that it is only when it is not due to choked disc, optic atrophy, or neuritis, and when it is not of the nature of hemianopsia, that it is to be thought a local symptom of quadrigeminal lesion. A defective action of the same branches of the oculo-motor nerves on both sides is rather more characteristic of quadrigeminal disease than the total affection of one nerve. Cases are yet too few to warrant more accurate statements.

VI. LESIONS OF THE TEGMENTUM OF THE CRURA CEREBRI, which lies beneath the corpora quadrigemina. Since the sensory tracts pass through this region, anæsthesia may be produced by such a lesion, and the proximity of the corpora quadrigemina would give rise to indirect local symptoms of their affection. Lesions of the red nucleus cause the symptom of incoordination which occurs when the posterior pair of the corpora quadrigemina are involved. They also cause paralysis of the third nerve, which passes through this nucleus. Lesions of the foot of the crus cerebri, in which the motor tract passes, cause hemiplegia of the opposite side. As the third nerve issues through the foot of the crus, a lesion here causes a paralysis of this nerve on the side of the lesion. Hence hemiplegia of one side, with third-nerve paralysis of the other side, indicates a lesion of the foot of the crus cerebri on the side of the third-nerve paralysis. Lesions on the base which press upon this part will produce the same combination of symptoms.

VII. LESIONS OF THE CEREBELLUM, if located in the hemispheres and not in the median or vermiform lobe, and if of such a nature as not to exert pressure on surrounding parts, may not produce any symptoms. If the lesion is in the vermiform lobe, disturbances of coordination known as cerebellar ataxia occur, which consist in an inability to walk without staggering like a drunken man. The ataxia exists only while the patient is in an upright position; it rarely affects the motions of the arms, and when it does it never interferes with the fine adjustments, but only with extensive movements in space, *e.g.*, grasping objects at a distance. These patients can stand with eyes closed without swaying. In these respects the ataxia differs from that of posterior sclerosis. A second characteristic symptom of cerebellar disease located in the vermiform lobe is vertigo. This may be very severe, but as it may occur without ataxia, and ataxia may be present without vertigo (though rarely), the two are not to be considered as interdependent. Vertigo is increased by rising to an erect position, but may persist when the patient is in bed. It decreases somewhat when the patient has remained fixed in any position for some time; but is always increased when he closes his eyes. The vertigo is usually an early symptom of cerebellar disease. It is more constant and persistent in cases in which the intracranial pressure is increased. It may gradually pass off in other cases. Cerebellar vertigo does not differ from vertigo in Ménière's disease, and is probably due to an affection of the terminal fibres of the eighth nerve, from the semicircular canals or their nuclei. The vertigo of Ménière's disease is, however, usually accompanied by deafness. Ataxia and vertigo together afford strong presumption of disease in the vermiform lobe, although neither alone is sufficient for a diagnosis.

The indirect local symptoms of cerebellar disease may be numerous. They are due to an affection of the tracts and nerve nuclei in the pons and medulla (see Fig. 871). Various forms of paralysis and anæsthesia, vaso-motor disturbances, obstinate vomiting of a projectile character, general symptoms of intracranial disease, *e.g.*, headache, optic neuritis, are usually present with tumors, abscesses, or hemorrhages in the cerebellum, especially if they are in the median lobe. The combination of cerebellar ataxia and vertigo with these and other symptoms of pons disease (see Section IX.) affords clear evidence of disease in the cerebellum.

Lesions of the cerebellum have no apparent effect upon the mental powers when they occur in adults. A deficient development of the cerebellum is, however, a frequent cause of congenital idiocy. When one cerebellar hemisphere fails to develop, the opposite olivary body in the medulla and the opposite hemisphere of the cerebrum usually present an atrophic appearance.

Lesions of the middle peduncles of the cerebellum, the crura cerebelli ad pontem, produce characteristic symptoms. These consist in a tendency on the part of the patient to assume a forced position, to turn toward or fall toward one side in walking, or even to revolve constantly about one axis of his body. The forced movements may be made by the eyes (conjugate deviation in one direction), by the head, or by the entire body. In a case seen by the writer, in which the autopsy showed a tuberculous tumor in the left middle peduncle and in the vermiform lobe, in addition to ataxia, vertigo, vomiting, and headache, the patient lay constantly on his left side, and when he turned upon his back or toward the right side the vertigo became so excessive that he was obliged to resume at once his former position. In walking, this patient showed a tendency to fail toward the right side, and found it impossible to turn around toward the right. Such patients may lose their balance in moving in one direction, *e.g.*, forward or backward, and in attempting to regain it they may be obliged to hasten their movements. This has been interpreted wrongly as a tendency to compulsory walking in one direction, *e.g.*, backward. It is really due to the vertigo. Lesions of the other peduncles of the cerebellum do not produce any known characteristic symptoms aside from those of cerebellar disease.

VIII. LESIONS UPON THE BASE OF THE BRAIN, tumors, chronic meningitis, may produce local symptoms by affecting the parts lying near them. Thus, all the cranial nerves may be involved either separately or in various combinations, and the nerve first or most severely affected may indicate where the lesion began. If such a lesion affects the optic nerve of one side, the optic chiasm, or the optic tract, blindness, either in the form of amaurosis of one eye or in that of hemianopsia of some variety, will be produced. If the lesion affects the crus cerebri or pons, the symptoms of lesion of this part (*vide supra* and Section IX.) may be present in addition to cranial-nerve paralysis. In all cases progressive bulbar paralysis is to be excluded before the diagnosis is made. The local symptoms of lesion of those parts of the cortex which lie on the base of the skull are undetermined, but a tumor of some extent which invades the left Sylvian region may cause aphasia from pressure upon the island of Reil. The variety of symptoms possible in basal disease can be determined by the study of the organs upon the base of the brain (see *Brain*), and any unusual combination of symptoms in intracranial diseases, especially if of syphilitic origin, should lead to a question as to the possibility of a lesion in this locality.

IX. LOCAL LESIONS IN THE PONS VAROLII AND MEDULLA OBLONGATA.—The pons Varolii and medulla oblongata lie upon the base of the brain, between the cerebrum and its crura above, the spinal cord below, and the cerebellum behind. Through them pass important tracts which join these organs with one another, and by means of which motor, sensory, vaso-motor, and trophic impulses are sent from the brain to the body, and from the body to the brain. Diseases in the pons and medulla cause symptoms of wide extent and serious nature, by interfering with the transmission of these impulses. The pons and medulla are not, however, merely organs of

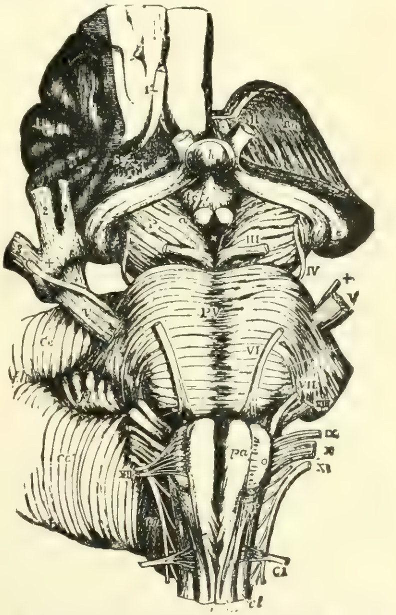


FIG. 875. The Base of the Brain and the Cranial Nerves. Pons and Medulla. *I* to *XII*, The cranial nerves; *Th*, optic thalamus; *h*, pituitary body; *tc*, tuber cinereum; *a*, corpora albicantia; *P*, pes pedunculi; *i*, internal, and *e*, external, geniculate body; *PV*, pons Varolii; *pa*, anterior pyramid of medulla; *o*, olive; *d*, decussation of anterior pyramids; *ca*, anterior column of spinal cord; *cl*, lateral column of spinal cord; *Ce*, cerebellum; *fl*, flocculus of cerebellum.

transmission. They contain centres of great importance, and preside over numerous functions. In them are located the nuclei of origin of the cranial nerves from the fifth to the twelfth inclusive, and through them the cranial nerves pass outward from these nuclei to the surface. In them are also situated complex automatic centres, which preside over the acts of combined movement of the eyeballs, deglutition, articulation, respiration, and cardiac inhibition, and which regulate the tone of the entire vaso-motor system, and the secretion of saliva, perspiration, and urine. Disease in the pons and medulla, by affecting these various centres, produces important symptoms, and the complexity of those symptoms is evident from the number of normal functions which will be interfered with in any case of extensive lesion. These functions and their affections must be considered separately.

1. *The Tracts Passing through the Pons and Medulla.*—These may be studied by the aid of a schematic drawing (Fig. 880), and by comparing a number of sections made at different levels through the pons and medulla (Figs. 877 to 888).

(1) *Tracts Connecting the Cerebrum and Cerebellum* (Fig. 876, A).—From the frontal lobe of each cerebral hemisphere tracts pass downward through the corona radiata, enter the anterior division of the internal capsule, and issue upon the base of the brain in the inner third of the pes pedunculi (Fig. 877, *p*). From the parietal, occipital, and temporal lobes of each hemisphere tracts pass downward through the corona radiata, enter the posterior division of the internal capsule, and issue upon the base of the brain in the outer third of the pes pedunculi (Fig. 877, *p*). A section through the crura cerebri at the level of the anterior corpora quadrigemina (Fig. 877), shows the pes pedunculi ($p+p'$) separated from the tegmentum by the substantia nigra (*sn*).

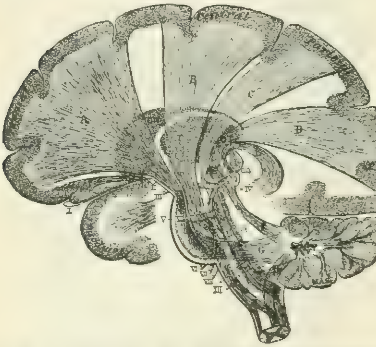


FIG. 876.—The Projection Tracts Joining the Cortex with Lower Nerve Centres. Sagittal section showing the arrangement of tracts in the internal capsule. A, Tract from the frontal lobe to the pons, thence to the cerebellar hemisphere of the opposite side; B, motor tract from the central convolutions to the facial nucleus in the pons and to the spinal cord; its decussation is indicated at K; C, sensory tract from posterior columns of the cord, through the posterior part of the medulla, pons, crus, and capsule to the parietal lobe; D, visual tract from the optic thalamus (O.T.) to the occipital lobe; E, auditory tract from the internal geniculate body (to which a tract passes from the VIII. nerve nucleus [J]) to the temporal lobe; F, superior cerebellar peduncle; G, middle cerebellar peduncle; H, inferior cerebellar peduncle; CN, caudate nucleus; C.Q., corpora quadrigemina; Vt., fourth ventricle. The numerals refer to the cranial nerves.

The outer and inner thirds of each pes (exclusive of the median fasciculus p^1) are made up of these tracts from the cerebral lobes. After passing through the pes these tracts enter the pons Varolii, where they are split up into small bundles by the transverse fibres of the pons. Sections through the pons Varolii at various levels (Figs. 878 to 883) show that the basal half of the pons consists of longitudinal and transverse bundles of fibres interlaced, and that considerable masses of gray matter, consisting of large polygonal cells, lie between the fibres. It is in these gray masses that the longitudinal bundles under consideration from the cerebral lobes terminate. Hence, in the sections through the lower portion of the pons (Figs. 882 and 883), fewer longitudinal bundles are seen than in the upper sections. From the masses of gray matter in the pons, the transverse fibres originate and pass laterally to the cerebellum. The majority of the fibres from one-half of the pons pass to the opposite hemisphere of the cerebellum, and thus cross the median line, where they interlace with those of the other side. The gray masses of the pons are thus interposed in a continuous tract between the cerebrum and the cerebellum; each cerebral hemisphere being connected with both cerebellar hemispheres, but to a far greater extent with the opposite hemisphere than with the one upon the same side.

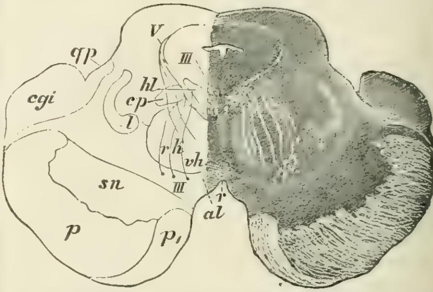


FIG. 877.—Section through the Crura Cerebri. (Wernicke, × 2.) *p*, Pes pedunculi; p_1, median fasciculus; *sn*, substantia nigra; *cgi*, corpus geniculatum internum; *qp*, corpus quadrigeminum posterior; *l*, lemniscus; *rk*, red nucleus of tegmentum through which pass fibres of oculomotor nerve, *III*, from its nucleus in the gray matter below the aqueduct of Sylvius, to its exit between the crura; *cp*, fibres in the formatio reticularis which have come from the posterior commissure; *hl*, posterior longitudinal bundle; *V*, descending root of the trigeminal nerve; *vh*, upper part of the decussation of the superior peduncles of the cerebellum, which end in the *rk*; *r*, raphé; *al*, lenticular loop.

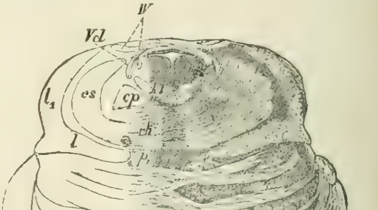


FIG. 878.—Section through the Pons. (Wernicke, × 2.) *sts* and *stc*, Superficial and deep transverse bundles of fibres intersecting the longitudinal bundles, and terminating in the masses of gray matter of the basal portion; p_1, median fasciculus of the pes; *l*, lemniscus; l_1, lower lemniscus; *rk*, red nucleus of tegmentum; *es*, superior peduncle of cerebellum, some fibres of which are decussating in the raphé; *cp*, fibres in formatio reticularis, which have come from the posterior commissure; *hl*, posterior longitudinal bundle; *Vd*, descending root of the fifth nerve; *IV*, fourth nerve decussating in the valve of Vieussens.

Lesions of the frontal, parietal, and occipital lobes, if extensive, are followed by degeneration in the tracts from these lobes to the masses of gray matter in the pons.

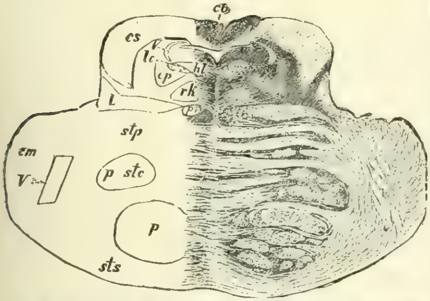


FIG. 879. Section through the Pons. (Wernicke, × 2.) *sts*, *stc*, *stp*, Superficial and deep transverse bundles of the pons, intersecting the longitudinal bundles, and terminating in the mass of gray matter of the basal portion; *p*, pyramidal (motor) tract from the middle third of the pes; p^1, median fasciculus of the pes, here seen to join the lemniscus, *l*; *V*, fifth nerve root; *cm*, middle peduncle of cerebellum; *cs*, superior peduncle of the cerebellum with *cb*, valve of Vieussens; *rk*, *hl*, *cp*; *V*, as in Fig. 878; *lc*, locus ceruleus.

Congenital absence of the cerebral cortex (Porencephalie) results in congenital absence of these tracts. Absence or atrophy of the cerebellum is attended by absence or atrophy of the transverse fibres of the pons, which join the cerebellar hemisphere with the gray masses of the pons. Congenital deficiency of one cerebral hemisphere is occasionally attended by atrophy of the opposite cerebellar hemisphere, and *vice versa*. The function of the tract from the cerebrum to the cerebellum is doubtless to maintain a communication between these organs. But the exact function is unknown, and lesions in the course of these tracts in the pons do not produce any known symptoms.

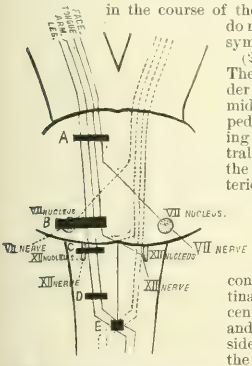


FIG. 880.—The Motor Tract in Pons and Medulla. Lesion at *A* causes hemiplegia of side opposite to lesion; lesion at *B* causes alternating paralysis; lesion at *C* causes paralysis of tongue on side of lesion and of extremities of opposite side; lesion at *D* causes paralysis of extremities of opposite side; lesion at *E* causes paralysis of extremities of both sides.

(2) *The Motor Tracts.*—These enter the upper border of the pons from the middle third of each pes pedunculi (Fig. 877), having come from the central convolutions through the corona radiata and anterior part of the posterior division of the internal capsule (Fig. 876, 2). Each motor tract, at its entrance into the pons, contains fibres whose destination is to the motor centres for the face, arm, and leg of the opposite side. But the centres of the facial nerve lie in the pons Varolii (Figs. 882 and 883). In its passage through the pons, therefore, the facial division of the motor tract leaves the remainder and crosses the median line. This crossing is made by way of the raphé, fibres leaving the longitudinal bundles in the ventral half of the pons, turning dorsad, entering the raphé, decussating with similar fibres from the opposite side, and then turning laterad to reach the facial nucleus (see Figs. 882 and 883). From the facial nucleus the facial nerve passes outward to the side of the pons, having first passed inward and curved around the abducens nucleus in the so-called knee of the facial nerve. The accompanying diagram indicates the course of the motor tract in the pons and medulla. As a result of the division of the motor tract of one side, lesions in the pons produce different forms of paralysis, according to their location. A lesion in the motor tract in the upper third of the pons causes hemiplegia of the side opposite to the lesion (Fig. 880, lesion at *A*). A lesion in the middle or lower third of the pons causes alternating paralysis, *i.e.*, paralysis of the face on the side of the lesion, with paralysis of the arm and leg on the opposite side (Fig. 880, lesion at *B*). In the first case (hemiplegia) the upper branch of the facial nerve is not affected, the patient can close his eye on the paralyzed side, and the facial muscles contract to the faradic electric current. In the second case (alternating paralysis) all branches of the facial nerve are involved, the eye remains open, and the reaction of degeneration develops soon after the lesion occurs. In this case it is usual to find a paralysis of the abducens nerve on the same side as the facial paralysis, in which case the eyeball will be turned in.

The motor fibres to the tongue take a similar course to those to the face, but leave the motor tract at a point in the lower third of the pons. Having reached the hypoglossal nucleus in the medulla they end, but the hypoglossal nerve passes outward, lying in close proximity to the motor tract in the medulla, as shown in the diagram. A lesion in the lower third of the pons or in the medulla may thus cause paralysis of one side of the tongue and of the opposite arm and leg (Fig. 880, lesion at *C*). In the medulla the motor tracts pass in the anterior pyramids (see Fig. 875, *pa*), and before entering the spinal cord undergo partial decussation. A lesion in one pyramid will cause paralysis of the opposite arm and leg (Fig. 880, lesion at *D*); but as the two pyramids lie side by side, lesions of the medulla, by affecting both at once, may produce paralysis of both arms and legs; and this is especially the case if the lesion lies so near the spinal cord as to involve the decussation (Fig. 880, lesion at *E*).

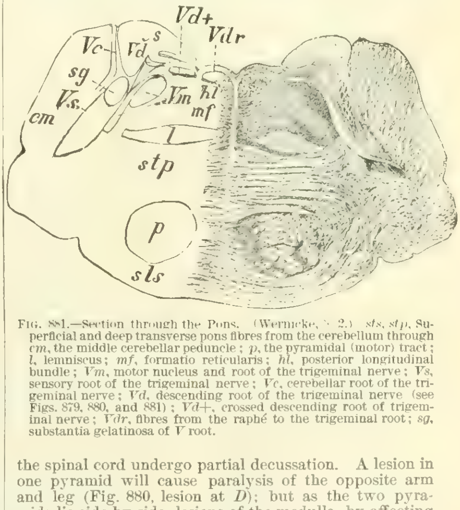


FIG. 881.—Section through the Pons. (Wernicke, × 2.) *sts*, *stp*, Superficial and deep transverse pons fibres from the cerebellum through *cm*, the middle cerebellar peduncle; *p*, the pyramidal (motor) tract; *l*, lemniscus; *mf*, formatio reticularis; *hl*, posterior longitudinal bundle; *Vm*, motor nucleus and root of the trigeminal nerve; *Vs*, sensory root of the trigeminal nerve; *Vc*, cerebellar root of the trigeminal nerve; *Vd*, descending root of the trigeminal nerve (see Figs. 879, 880, and 881); *Vd+*, crossed descending root of trigeminal nerve; *Vdr*, fibres from the raphé to the trigeminal root; *sg*, substantia gelatinosa of *V* root.

The various forms of paralysis produced when both sides of the pons are involved at once can be ascertained by reference to the diagram.

In all these affections of the motor tract a condition of spastic rigidity may follow the paralysis, and an increase of tendon reflexes is usually observed. In a few cases of pons lesion, however, the tendon reflexes have been lost.

The electric condition of the paralyzed muscles in the limbs is normal from the outset, and no rapid atrophy occurs.

The situation of the pyramidal tract is seen in all the figures at *p*. In the upper part of the pons (Figs. 878 and 879) its fibres are seen to be split up into small bundles by the transverse pons fibres. In the middle of the pons, however (Fig. 881), they have collected together, and in the lower part of the pons (Figs. 882 and 883) they form a compact tract which continues downward in the anterior pyramid of the medulla (Figs. 884 to 887, *p*). At the lowest level of the medulla (Fig. 887) the pyramidal fibres decussate, and thus pass into the lateral columns of the spinal cord. About one-fifth of the pyramidal fibres do not, however, take part in the decussation, and these continue downward in the anterior median columns of the spinal cord. The ratio of decussating to non-decussating fibres was found by Flechsig to vary greatly, and in one case in sixty no decussation occurs. The relative sizes of one lateral pyramidal tract and of the opposite anterior median column of the spinal cord depend wholly upon the extent of the decussation of the pyramids in the medulla.

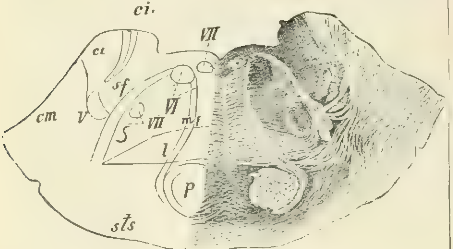


FIG. 882.

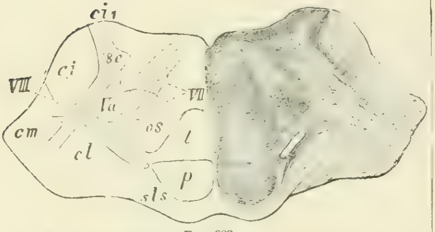


FIG. 883.

FIGS. 882 AND 883. Sections through Pons. (Wernicke, × 2.) *sts*, superficial transverse pons fibres from cerebellum through *cm*, middle cerebellar peduncle; *p*, pyramidal tract; *l*, lemniscus; *mf*, formatio reticularis; *VI*, abducens nucleus from which abducens nerve passes forward, lying near *p*; *VII*, facial nucleus lying deep in *mf*, sending its fibres backward toward the floor of the ventricle (Fig. 882), where they turn upward (Fig. 883), and then curve outward, thus forming a bend or knee around the *VI* nucleus; *Va*, ascending root of trigeminal nerve; *ci*, inferior cerebellar peduncle; *VIII*, auditory root; *8e*, external auditory nucleus; *ct*, corpora trapezoides; *os*, superior olive.

(3) *The Tract of Muscular Sense.*—This is called the lemniscus or fillet in the pons, and the interolivary tract in the medulla. As it conveys sensations upward we trace it in that direction. It arises from the nuclei gracilis and cuneatus on the dorsal surface of the medulla, in which the columns of Goll and Burdach of the spinal cord end (Figs. 887 and 888, *ft* and *fc*). It then crosses the median line, decussating with its fellow of the opposite side in the upper decussation of the medulla (sensory decussation of Meynert; pinniform decussation of Spitzka) (Fig. 887, *l*, *ft*). The fibres after decussating turn upward, enter the interolivary tract, and pass onward through the medulla beyond the upper level of the olives into the pons (Figs. 884 and 885, *l*). Here this tract broadens out, becoming almost ribbon-like in its appearance, and hence has been called the fillet. In the pons the fillet lies behind the deep transverse bundles of the pons, and just in front of the formatio reticularis (see Figs. 878 to 883, *l*).

As it passes up it receives additional fibres from the superior olive (Fig. 884, *o*, *s*), but these leave it again at the level of the posterior corpora quadrigemina (Fig. 878, l^1), while the main part of the fillet passes onward in the outer part of the tegmentum of the crus cerebri (Fig. 876, *l*), and thence into the posterior part of the internal capsule, whence it radiates to the parietal cortex of the brain.

Sensations of muscular sense being transmitted by this tract, a lesion in it causes ataxia in the limbs of the opposite side. A unilateral ataxia may indicate a lesion in the course of the fillet.

(4) The *Sensory Tract*, which transmits sensations of touch, temperature, and pain through the medulla and pons, is in the formatio reticularis. This portion of the medulla and pons lies just beneath the gray matter of the floor of the fourth ventricle, behind the tracts hitherto described. It is made up of nerve fibres passing in three directions: (*a*) transversely, the commissural fibres of the cranial nerve nuclei; (*b*) from the nuclei ventrad, the fibres of the cranial nerve roots and arciform fibres; (*c*) longitudinally, the sensory tract. The longitudinal fibres can be traced from the gray matter and various columns of the spinal cord, through the formatio reticularis to its upper level in the tegmentum of the crus, whence they issue to enter the posterior part of the internal capsule. In the medulla the formatio reticularis of each side is divided into two parts by the line of exit of the nerve roots of the twelfth (see Fig. 885). The inner part, near the median line, contains the continuation of the anterior and antero-lateral columns of the spinal cord, and the interolivary tract or lemniscus already described. The outer part contains the sensory tract now under consideration. In the inner two-thirds of this outer part the fibres pass which convey impressions of touch, temperature, and pain from the opposite half of the trunk

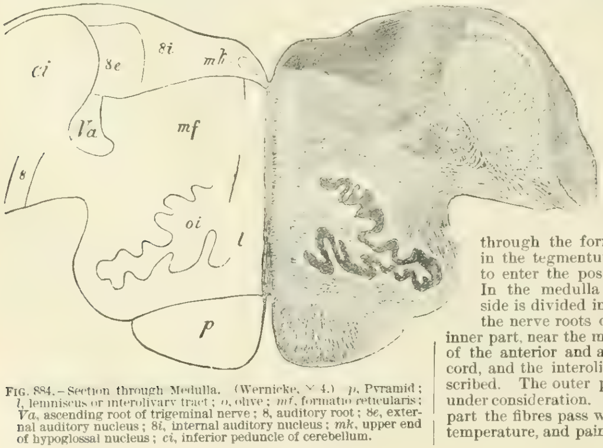


FIG. 884.—Section through Medulla. (Wernicke, × 4.) *p*, Pyramid; *l*, lemniscus or interolivary tract; *o*, olive; *mf*, formatio reticularis; *Va*, ascending root of trigeminal nerve; 8, auditory root; *8e*, external auditory nucleus; *8i*, internal auditory nucleus; *mk*, upper end of hypoglossal nucleus; *ci*, inferior peduncle of cerebellum.

and limbs. In the outer third of this part is found a column of peculiar structure resembling the substantia gelatinosa of the posterior horn of the spinal cord, and in this column terminate the fibres of the sensory part of the trigeminal nerve (Figs. 884 and 885, *Va*), which turn downward after entering the pons Varolii, and terminate at different levels in the pons and medulla (see Fig. 886). Thus the outer portion of the formatio reticularis contains the sensory tract from the face of the same side. It is evident from the diagram that a lesion which involves one-half of the formatio reticularis in the pons and medulla will produce an alternating anæsthesia, *i.e.*, loss of sensation on one side of the body and on the other side of the face and head (lesion at *B*, Fig. 886). Alternating anæsthesia is as characteristic a symptom of lesions of the formatio reticularis of the pons and medulla, as alternating paralysis is of lesions in the motor tract of the pons. In the upper part of the pons the sensory tract from the face crosses the median line, and hence a lesion in the formatio reticularis in the upper third of the pons, or in the crus cerebri, will produce a unilateral anæsthesia (lesion at *A*, Fig. 886; see Fig. 881, *Vdr*, *Vd+*). A lesion involving both halves of the formatio reticularis will produce bilateral sensory symptoms.

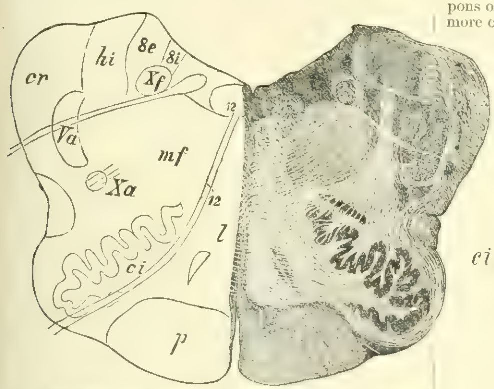


FIG. 885.—Section through Medulla. (Wernicke, × 4.) *p*, Pyramid; *l*, lemniscus or interolivary tract; *ci*, fibres from the olive which cross the raphé and pass outward and backward to enter the inferior cerebellar peduncle, *cr*; *mf*, formatio reticularis, in which *Xa*, the deep nucleus of the vagus (nucleus ambiguus), lies; *Va*, ascending root of trigeminal nerve; 12, hypoglossal nucleus and root; *Xf*, respiratory bundle around which, in the floor of the ventricle, the vagus nucleus lies, and below which the vagus root issues; *8e* and *8i*, auditory nuclei; *hi*, nucleus cuneatus, from which fibres pass outward and enter *cr*.

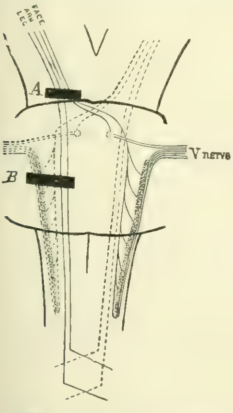


FIG. 886.—The Course of the Sensory Tract in Pons and Medulla. *A*, Lesion in tegmentum of crus cerebri, or upper quarter of pons, producing hemianæsthesia of the opposite side; *B*, lesion in formatio reticularis of pons or medulla, producing alternating anæsthesia.

It is evident that a lesion of any extent, either in the pons or in the medulla, will inevitably destroy one or more of these four tracts, and consequently will produce serious symptoms of wide extent and of considerable diversity.

2. *The Centres Lying in the Pons and Medulla.*—The cranial-nerve nuclei lying in the pons and medulla must be briefly enumerated, since lesions affect them. They are located either in the gray matter of the floor of the fourth ventricle, or below this in the formatio reticularis.

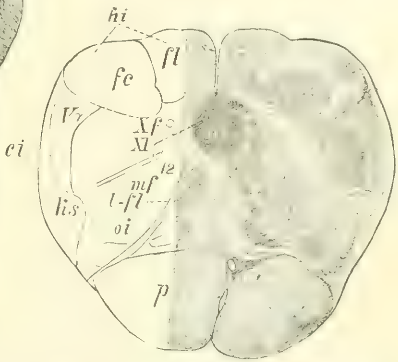


FIG. 887.—Section through Medulla, Level of Sensory Decussation. (Wernicke, × 4.) *ft*, Nucleus gracilis; *fc*, nucleus cuneatus, from which fibres curve around the central gray, and then decussate and turn upward (cephalad) in the interolivary tract, *l-ft*; *Va*, ascending root of the trigeminal nerve; *ci*, inferior peduncle of cerebellum, of which *ks*, direct cerebellar column of the cord, is a part; *Xf*, respiratory bundle; *XI*, medullary nucleus of spinal accessory nerve and its root; 12, hypoglossal nucleus and root; *mf*, formatio reticularis; *oi*, olive.

Figs. 889 and 890 show the relative position of the cranial-nerve nuclei in the pons and medulla from the fifth to the twelfth, inclusive.

The third and fourth nerve nuclei and roots, together

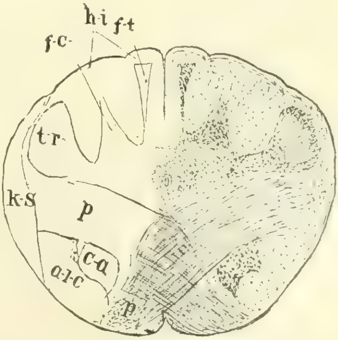


FIG. 888.—Section through Medulla, Level of Motor Decussation. *hi*, Posterior columns of spinal cord; *ft*, nucleus gracilis in column of Goll; *fc*, nucleus cuneatus in column of Burdach; *tr*, tubercle of Rolando, where posterior horn of spinal cord merges into *Va*, ascending root of *V*; *ks*, direct cerebellar column; *p*, pyramid decussating to reach lateral column; *ca*, anterior cornu of cord; *alc*, antero-lateral column of cord.

with the effect of lesions in them, will be discussed in the article on *Ophthalmoplegia.*

The cranial nerves from the fifth to the twelfth may be considered in two categories. first, the motor nerves; second, the sensory nerves.

(1) The *Motor Nerves* are the motor branch of the trigeminal which supplies the muscles of mastication, the abducens, the facial, the motor portion of the glossopharyngeal and of the vagus, the spinal accessory, and the hypoglossal.

Lesions which irritate the tracts from the cortical centres to these nuclei, or lesions in their vicinity which cause irritation, may produce spasm of the muscles supplied by them. Thus spasm of the jaw (trismus), with grinding of the teeth, nystagmus, conjugate lateral deviation of the eyes, spasm of the face, spasm of the throat and larynx, and spasm of the tongue may occur from lesions of an irritating nature. Such are small hemorrhages, small areas of softening, or small tumors in the pons or medulla. Such lesions must lie in or near the floor of the fourth ventricle, or in the course of the nerve roots, to produce these spasms. A review of recent literature shows that they are to be regarded as rare symptoms. If such spasms occur alone, without other symptoms, it is difficult to determine the nature of the lesion, or to decide that the spasm is not functional. If they occur in connection with other symptoms of pons or medullary lesion, they are valuable as evidence of the exact position of the disease.

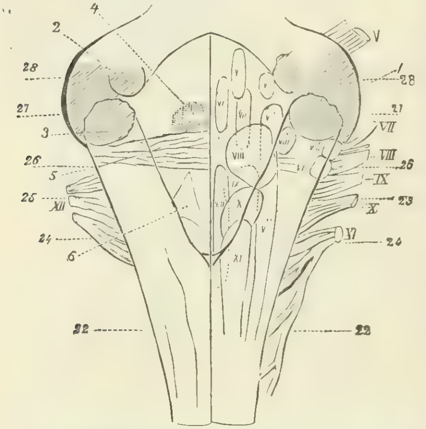


FIG. 889.—Diagram Showing the Position of the Cranial Nerve Nuclei upon the Floor of the Fourth Ventricle (Erb). *v* to *xii*, Nuclei; *V* to *XII*, cranial nerves; *v*, median of *V*; *v'*, motor nucleus of *v''*, ascending root of *V*; *viii*, inner nucleus of *VIII*; *viii'*, outer nucleus; *viii''*, *viii'''*, lateral nuclei of *VIII*; 27, middle cerebellar peduncle; 3, inferior cerebellar peduncle; 2, superior cerebellar peduncle; 4, eminenter teres; 5, striæ acusticæ; 6, ala cinerea.

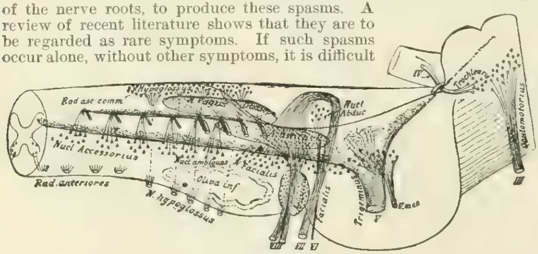


FIG. 890.—Longitudinal Section Showing the Relative Position of the Cranial Nerve Nuclei (Edinger).

Lesions which interrupt the tracts from the cortical centres to the motor-nerve nuclei, which destroy those nuclei, or which interfere with the conduction of impulses along the nerve root and nerve trunk, will produce paralysis. Paralysis of the muscles of mastication is the rarest form of paralysis. Paralysis of the external rectus muscle, or of the facial muscles and tongue, is very common. Paralysis of deglutition or of the vagus is occasionally met with. It is easy to determine in any case whether the paralysis is due to lesion of the central tracts, or to lesion of the nerve nuclei. In the first case atrophy does not follow the paralysis, and there is no change in the electric reaction in the muscles. In the second case atrophy occurs soon after paralysis, and is accompanied by a reaction of degeneration. But the latter symptoms are common to lesion of the nerve root and trunk as well as to lesion of the nucleus; hence other symptoms are necessary to establish a diagnosis of a lesion in the nucleus. When paralysis of the muscles supplied by one cranial nerve occurs alone, the probability is in favor of a peripheral nerve lesion, *e.g.*, a meningitis or tumor on the base of the brain; and a central lesion can be thought probable only when an implication of other muscles in the domain of other nuclei ensues.

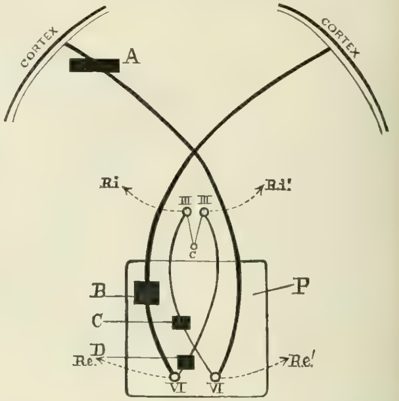


FIG. 891.—The Innervation of the Muscles of the Eye. (After Hunnius, "Zur Symptomatologie der Brückenerkrankungen.") P, Pons Varolii; III, oculomotor nuclei, with R.i., nerve to left internal rectus, and R.i.', to right internal rectus; VI, abducens nuclei, with R.e., nerve to left external rectus, and R.e.', to right external rectus; tract from cortex to VI conveys voluntary impulses of conjugate deviation of the eyes; tract from VI to III unites the action of one external rectus with the opposite internal rectus; C, centre for convergence of the eyes which is independent of VI and is actually in connection with the cortex by independent tracts not shown; A, situation of a lesion in the cerebrum producing loss of voluntary conjugate deviation of the eyes to the right; B, situation of a lesion in the pons producing loss of voluntary conjugate deviation of the eyes to the left; C, situation of lesion in the pons in the posterior longitudinal bundle, causing paralysis of conjugate motion to the right; D, situation of a lesion in the pons in the posterior longitudinal bundle, and involving the VI nucleus, causing loss of conjugate motion to the left, with permanent deviation of the eyes to the right.

Paralysis of the external rectus is so common that it requires some attention. It is usually due to a lesion on the base of the brain outside of the pons, involving the sixth nerve. It may be due also to lesion in the pons between the nucleus of the sixth nerve and the exit of the root (see Fig. 882). In both cases there will be a permanent deviation of the eye inward and an inability to turn it outward, with contraction of the pupil.

But abducens paralysis may also be due to a lesion of the abducens nucleus in the pons. In such cases there is the added symptom of inability to perform conjugate movement of both eyes toward the side of the lesion, and a permanent deviation of both eyes to the opposite side. But this deviation does not prevent the voluntary act of convergence of both eyes to a near point. Lastly, abducens paralysis may be due to lesions in the crus, or between the crus and the cortex, in the course of the tract conveying voluntary impulses from the cortex to the sixth-nerve nucleus. Such lesions will interfere with voluntary conjugate movement of both eyes to one side, viz., toward the side whose abducens is paralyzed. But since such a lesion may lie in the pons after the decussation of this tract, or in the cerebrum before its decussation, it cannot be said that the deviation is uniformly either toward or away from the lesion. In this case there is no permanent deviation of the eyes to either side; for the abducens nucleus being uninjured, it maintains the tone of the external rectus muscle, and during rest the eyes are found directed forward. If a lesion in the course of the central tract is of an irritative nature, however, it may cause forced motions of the eyes by sending impulses to the sixth nucleus. Under these circumstances there will be conjugate deviation of both eyes toward the side of the abducens paralysis.[1] The act of conjugate movement may also be interfered with, without paralysis of the abducens nerve. That act is governed by the sixth nerve nucleus, or by a special nucleus in its immediate vicinity as yet undetermined. It involves an innervation of one external rectus muscle and of the opposite internal rectus muscle. But the internal rectus muscle derives its innervation from the third nerve. A crossed connection must therefore be maintained between the abducens of one side and the oculo-motorius of the other side. This connection is maintained by means of the posterior longitudinal fasciculus (Figs. 877 to 883, *hl*). A lesion in the pons in the course of this bundle will interfere with the act of conjugate movement without paralyzing either abducens or oculo-motor nerve alone. In none of the cases mentioned is voluntary convergence of the eyes to a point suspended. These conditions may be understood by reference to Fig. 891.

A very extreme contraction of the pupils is mentioned as a symptom in cases of sudden lesion of the pons. It has not been explained.

Paralysis of the facial muscles is very common, but is usually due to lesions in the nerve outside of the pons. The symptoms which are produced when the facial nerve root or its nucleus is invaded in the pons, resemble those of Bell's palsy; for all the facial muscles are affected, and an atrophy with reaction of degeneration ensues. The situation of the lesion in the pons can be determined only when other symptoms of pons disease, such as alternating paralysis (Fig. 880), are present.

Paralysis of the motor portion of the glosso-pharyngeal nerve, with dysphagia or difficulty of swallowing, is a not infrequent symptom of pons disease. It occurs after sudden lesions, such as hemorrhage or embolism, also as the result of tumors, and most frequently of all in progressive bulbar paralysis.

Paralysis of the motor and vaso-motor mechanisms, governed by the vagus nerve, is a constant symptom of disease in the lower part of the pons and in the medulla. Arrest of respiration and heart action, from lesion of this nucleus, is the cause of sudden death, which so frequently attends sudden lesions in the medulla and pons. When the lesion is, however, of a slowly progressive nature (tumor, sclerosis about a hemorrhage), symptoms of irritation may occur from gradual invasion of the pneumogastric centres. Projectile vomiting; slow or very rapid, or intermittent, irregular pulse; dyspnœa; loss of voice; polyuria and glycosuria, are symptoms which have been ascribed to such lesions. The two last-named symptoms have been associated with tumors in the lower part of the medulla[2] and upper part of the spinal cord, which have involved the fibres from the vaso-motor centre on their way downward to their exit from the cord at the eighth cervical segment. The intramedullary nucleus of the spinal accessory nerve is so closely adjacent to that of the vagus that they are usually involved together, when difficulty of respiration and articulation ensues. When the spinal portion of the nerve is affected, spasms of the neck occur; but this symptom is characteristic of meningeal affections, and has not been observed in central lesions.

An affection of the hypoglossal nerves or their nuclei is very frequently observed in medullary disease, partly because the nerves pass through the middle of the medulla, and partly because their nuclei are large. If the lesion produces irritation of one nucleus, fibrillary twitchings and spasm in one-half of the tongue may be caused. It is more usual to find paralysis than spasm, in which case the tongue, when protruded, will deviate toward the paralyzed side, and will, therefore, point toward the lesion. But when the tongue is affected by disease in the medulla, it is not unusual for both halves to be involved, and then it is found that the power of protruding it is suspended, and motions in the mouth are also difficult. Hence talking, chewing, and swallowing are interfered with. An electric examination in these cases will demonstrate the reaction of degeneration in the intrinsic muscles of the tongue, and prove that the lesion is medullary, and not cerebral. Anarthria or dysarthria, *i.e.*, imperfect articulation, is, according to Nothnagel, a frequent and important symptom of medullary disease.

(2) The *Sensory Nerves* of the pons and medulla are the trigeminal, the auditory, and the glosso-pharyngeal. Lesions which affect the trigeminal nerve and produce anæsthesia of the face have already been considered. Trophic disturbance of the eyeball has not yet been observed in cases of lesion of the trigeminal root or nucleus. The auditory nerve is occasionally affected in diseases of the pons and medulla. Two sets of symptoms are then produced: one referable to the implication of the fibres conveying auditory impressions, the other due to the irritation or destruction of fibres concerned in the sense of equilibrium. Deafness has been observed in pons disease on the side of the lesion,* and is probably due to destruction of the auditory fibres passing inward to the inner auditory nucleus on the floor of the fourth ventricle, or to an implication of that nucleus (see Fig. 884). The central course of the auditory tract is believed to be as follows: From the inner and outer auditory nuclei fibres cross the median line in the corpus trapezoides (Fig. 883, *ct*) to the opposite superior olive, thence turn upward with the lemniscus, pass beneath the posterior corpora quadrigemina in the lower lemniscus (Fig. 877, l^1), and thus reach the internal geniculate body, from which a tract passes outward through the lower posterior part of the internal capsule and corona radiata to the temporal lobe of the brain (Figs. 876, 884). The course of this tract has been traced by anatomists, and has not yet been confirmed by pathological observation. Lesions at any part of it should produce deafness in one ear. Disturbance of equilibrium may occur from lesions in the lateral portion of the pons, if such lesions interrupt the part of the auditory nerve conveying such sensations to the cerebellum. This part of the auditory nerve passes either directly into the cerebellum through the inferior peduncle, or terminates in the external auditory nucleus, which is connected by fibres with the cerebellum (Figs. 882, 883, *e*, ci^1). Vertigo, which is a frequent symptom of pons lesion, and rotatory movements of the body toward one side, which is an occasional symptom of pons disease when the lesion involves the lateral portion of the pons, and the inferior and middle cerebellar peduncles, are probably due to an involvement of this portion of the auditory nerve in the lesion. The rotatory movement is probably due to a voluntary attempt to correct a subjective sense of motion. The patient really suffers from vertigo, and thinks that he is turning or falling

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* It is recorded in five cases in twenty-six. In other cases it may have been present, but was not recorded (Starr: "The Sensory Tract in the Central Nervous System," Jour. of Ment. and Nervous Disease, July, 1884).

toward one side; he therefore tries to prevent this falling by turning toward the other side. The symptom may be so serious that such rotatory movements are constantly kept up until the patient dies of exhaustion. The patient turns toward the side opposite the lesion (?).

The sensory portion of the glosso-pharyngeal nerve receives the sensations of taste,[3] and in two cases in which its nucleus has been involved a loss of taste has occurred. This symptom is so rarely elicited that it is not known whether lesions elsewhere in the pons or medulla will produce it.

The Vaso-Motor Centre.—Lesions in the upper half of the medulla produce marked vaso-motor symptoms.[4] They consist of a general vaso-motor paralysis with flushing of the surface and sensation of heat, and of abnormal sweating. The vaso-motor centre is bilateral, and each centre controls the circulation on the same side of the body. Lesions in its area are so likely to cause sudden death that but few cases can be found in which it was affected (eight cases in my collection). But the symptoms of a vaso-motor character are to be looked for in any case of medullary lesion, and when such symptoms are limited to one lateral half of the body, and are associated with other symptoms of bulbar disease, they are valuable as signs of the situation of the lesion.

There are a few general symptoms that have been not infrequently observed in pons disease which require mention. General convulsions are the most constant of these. The majority of sudden lesions (hemorrhage, embolism) in the pons are ushered in by general convulsions, followed by coma. Nothnagel established the fact that in animals irritation of the pons produces general convulsions, and hence authors have spoken of a convulsive centre in the pons. It is hardly warrantable to hypothecate such a centre. But it is probable that lesions in the pons are capable of producing general convulsions by irritating the motor tracts which pass through it. This is borne out by the fact that when the lesion is a tumor or a sclerosis, *i.e.*, a gradually increasing lesion, convulsions do not occur. Headache, disturbance of vision, vertigo, and psychical changes have been frequently observed in connection with diseases of the pons and medulla, but they are to be ascribed to changes in the circulation or internal cranial pressure, and not to any special local lesion.

It is evident from this review that the symptoms of lesions of the pons and medulla are very numerous, very complex, and very various, in accordance with their extent and the manner of their occurrence. The symptoms in bulbar paralysis are very different from those of softening from embolism. And as almost every case so far recorded has differed from every other in important particulars, it is necessary to study carefully and fully all the symptoms occurring in any case of central lesion. If the cranial nerves are involved, or if there is present alternating paralysis or anæsthesia, the possibility of pons or medullary disease must be considered, and an investigation of the various symptoms here detailed should not be neglected.

M. Allen Starr.

BRAIN: EMBOLISM AND THROMBOSIS.—EMBOLISM.—*Etiology.*—Cerebral embolism is almost always the result of an endocarditis, either acute or chronic, of the left side of the heart. In acute ulcerative endocarditis the emboli are usually very small, and lodge in the capillaries. This form of the disease will not be discussed in this article.

The embolus consists generally of small, soft particles of fibrin which have been detached by the current of blood from the vegetations on the valves of the heart. But the embolus may also be composed of calcified particles, or of pieces of the valves which have been separated by the ulcerative process from the main part of the valve. Less frequently the embolus is detached from a cardiac thrombus, situated often in the left auricular appendix, or near the apex of the left ventricle.

In rare instances the embolus is derived from the right side of the heart, and such cases have been explained either by the patency of the foramen ovale, or by the transmission of the embolus through one of the pulmonary veins, which are said to constitute a direct communication between the right and left sides of the heart. Cohnheim reports a case of embolism of the middle cerebral artery owing to thrombosis of the veins of the lower limb. In this case the foramen ovale readily admitted three fingers. So far as we are acquainted with the literature of the subject, this is the only case of the kind on record.

Myocarditis may also give rise, though very rarely, to cerebral embolism by causing rupture of the endocardium, and the consequent admixture of the products of inflammation with the blood. This is also true of gummatous or other growths in the substance of the heart, which proliferate through the endocardium.

Another source of embolism is found in atheromatous degeneration and calcification of the inner coats of the aorta, with subsequent deposit of fibrin, and in aneurism of the same vessel. Embolism may result also from thrombosis of one of the arteries in the circle of Willis, a portion of the thrombus becoming detached and giving rise to an embolus in one of the more peripheral vessels in the brain.

Cerebral embolism may also result from gangrenous or other processes in the lungs, which have caused ulceration and finally perforation of a vein, and thus permit the entrance of the gangrenous or other material into the blood. This mode of development has been referred to previously in the discussion of abscess of the brain.

Tumors may give rise to embolism in the same way. Another equally rare cause of embolism is the existence of wounds, phlegmonous inflammations involving the subcutaneous adipose tissue, and complicated fractures of the bones in which inflammatory processes are set up in the medulla of those organs.

Von Dusch maintains that many of the cases of sudden death in pleurisy during aspiration, or while the pleura is being washed out, are due to the formation of thrombi in the pulmonary veins. He believes that the development of paralysis, which is observed sometimes under such circumstances, may be explained by the secondary occurrence of cerebral embolism. Indeed, in one instance of this kind, the cerebral emboli were discovered at the post-mortem examination. Finally, mention should be made of the capillary pigment emboli of the brain, seen occasionally in severe forms of intermittent and remittent fever. These emboli may be so numerous as to give the brain a chocolate color. All the cases of the kind which have come under our observation have originated in Central or South America.

In our experience cerebral embolism occurs much more frequently in males than in females, but, according to Gowers, it is more frequent in women, owing, as he claims, to the greater frequency of mitral stenosis in females.

Pathological Anatomy.—Cerebral emboli (with the exception of the capillary emboli, which will not be discussed in this article) are usually single, and, in the majority of cases, are situated in the left middle cerebral artery. This predilection is explained by the fact that the current of blood from the aorta passes by a straighter course into the left carotid than into the right carotid, and that, furthermore, the left middle cerebral artery is the direct continuation of the carotid. It has been claimed by Gelpke, on the basis of statistics, that the left middle cerebral presents only a slight preponderance over the right middle cerebral in this respect, but this is probably owing to the fact that, on account of the usual situation of the embolus in the vessel on the left side of the brain, the history of such cases is not generally reported.

In a certain proportion of cases the emboli are situated

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[1] See Report of Clinical Society, Lancet, March 18th, 1887.

[2] Archiv für Psychiatrie, xiii., S. 658 u. S. 671.

[3] C. L. Dana: Jour. Nerv. and Ment. Dis., xiii., 65, 1886.

[4] M. A. Starr: The Sensory Tract in the Central Nervous System. Jour. Nerv. and Ment. Disease, xi., July, 1884; also, Vaso-Motor Neuroses, Pepper's System of Medicine, vol. v.

in other vessels, and even two or more may be present at the same time.

The following is a brief *résumé*, according to Duret, of the distribution of the blood-vessels to the brain. These vessels may be divided into two classes: First, those which are given off at the base of the brain and at once enter the organ to supply the parts situated above (basal ganglia, etc.); and secondly, the continuations of these vessels which supply the cortex. We shall first describe the former.

The anterior cerebral and anterior communicating arteries send off a number of small branches which supply the anterior part of the corpus striatum.

The posterior cerebral artery sends branches to the walls of the third ventricle, the optic thalamus (mainly the posterior portion), the tegmentum of the crus cerebri, and the corpora quadrigemina.

The middle cerebral artery (the most important artery of the brain) gives off a number of branches before it supplies the cortex: (1) The internal striate arteries to the first and second divisions of the lenticular nucleus and the internal or white capsule; (2) the lenticulo-striate arteries which supply the anterior part of the third division of the lenticular nucleus and of the internal capsule, and also pass to the corpus striatum; (3) the lenticulo-optic arteries which pass to the posterior part of the third division of the lenticular nucleus and the anterior portion of the optic thalamus.

Following is the cortical distribution of these vessels:

The anterior cerebral artery supplies the convolutions on the inferior surface of the frontal lobe, the first and second frontal convolutions, the paracentral lobule, and the præcuneus.

The posterior cerebral artery supplies the gyrus uncinatus and hippocampus, the inferior surface of the temporo-sphenoidal lobe, and the occipital convolutions.

The middle cerebral breaks up into five branches: (1) To the third frontal (Broca's) convolution; (2) to the ascending frontal convolution; (3) to the ascending parietal convolution; (4) to the inferior parietal and superior temporo-sphenoidal convolutions; (5) to the first and second temporo-sphenoidal convolutions.

The pons Varolii and medulla oblongata are supplied in the following manner:

The basilar artery gives off vertical branches, which supply the nuclei of origin of the nerves and the ependyma of the fourth ventricle. The nuclei are also supplied by small vessels, which enter with the roots of the nerves.

The inferior cerebellar artery supplies the lateral parts of the medulla and the inferior cerebellar peduncle. The remaining portions of the pons and medulla, and the cerebellum, are supplied by the transverse and cerebellar arteries.

The vessels which enter the substance of the brain from the base are terminal arteries, *i.e.*, there is no anastomosis between the distribution of one vessel and the adjacent ones. A certain amount of anastomosis exists between the vessels which ramify in the pia mater, but this is very often insufficient to compensate for the anæmia produced by the plugging of one of these arteries.

When a terminal artery is completely obstructed by an embolus, the supply of arterial blood to the distribution of the vessel is shut off. According to Cohnheim, the reflux of blood from the corresponding vein will gorge the capillaries with blood. Litten believes that the filling of the capillaries is due to the influx of blood from the capillaries of adjacent regions. If the blood pressure is too feeble, however, this feature is not observed.

As a result of the cessation of circulation in the territory supplied by the obstructed vessel, the nutrition of the capillaries and veins becomes impaired, and they therefore permit the escape of red blood globules. Then the tissues which have been deprived of blood undergo simple fatty degeneration, and an infarction is produced. Finally, absorption occurs, leaving a cyst containing clear fluid.

If a reflux of blood into the vessels does not take place, the infarction has a yellowish or whitish color from the beginning, but in other respects the course is the same as that just described. The retrogressive changes (necrobiosis) probably begin at the end of thirty-six or forty-eight hours. Some authorities think that these changes begin at the end of two or three hours.

Unlike what takes place in embolism of other organs of the body, embolism of the brain does not often produce a hemorrhagic infarction, but almost always results in a patch of yellow or white softening. The reason for this difference is not very clear.

When the embolus is lodged in one of the vessels supplying the cortex, the effect produced varies according to the size of the vessel and the extent to which it anastomoses with surrounding ones. Infarctions in this region are usually of small size, though they occasionally attain much larger dimensions than those situated within the brain, particularly if a large branch of the middle cerebral artery has been occluded. The color of the infarction is yellow or brown, and the external surface is often extremely hard. It diminishes in extent toward the interior, and sometimes involves only the gray matter of the convolutions. On the other hand, the white matter below the convolutions may alone be affected, while the cortex escapes. The pia mater above the lesion is usually infiltrated with fluid, and is readily detached from the surface.

In old cases in which the motor regions have been involved, either within the brain or in the cortex, descending degeneration of the pyramidal tracts occurs as it does in cerebral hemorrhage. Moreover, I have occasionally seen atrophy of the unaffected parts of the hemisphere after extensive lesions of this kind, though not to so marked an extent as that which I have described as occurring in cerebral hemorrhage.

Clinical History.—From the nature of the disease, the symptoms of cerebral embolism always begin suddenly. The attack may or may not begin with a disturbance of consciousness, and, as in cerebral hemorrhage, this may vary from a passing vertigo or feeling of confusion to complete and profound unconsciousness. General or unilateral convulsions also constitute a not infrequent accompaniment of the attack. The symptoms during the stage of unconsciousness differ in no respect from the corresponding ones of cerebral hemorrhage, but they are not apt to be so prolonged, and, moreover, there are no characteristic phenomena connected with the bodily temperature. There is usually a slight rise of temperature soon after the development of the seizure, but afterward it varies irregularly from time to time. In fatal cases the temperature usually rises steadily until death.

As the embolus is situated commonly in one of the arteries of the left side of the brain (usually the middle cerebral), right hemiplegia usually results, and in a considerable proportion of cases is associated with aphasia. In fact, the sudden occurrence of right hemiplegia and aphasia, without previous head symptoms, is *prima facie* evidence that we have to deal with an attack of embolism of the left middle cerebral artery.

The character of the aphasia differs greatly in individual cases according to the situation of the lesion, and all the different varieties of aphasia may thus be produced (*vide* the article on *Aphasia*, in Vol. I.). In some cases, indeed, aphasia is the only symptom produced, and may remain permanent without being followed by any other symptom. In a case which came under my observation it was associated with epileptiform convulsions, which recurred at irregular intervals.

At other times the aphasia is a temporary symptom which soon disappears, but is followed later by an apoplectiform attack, attended with hemiplegia, which then runs the usual course.

The duration of the hemiplegia varies within very wide limits. If recovery does not take place within a few weeks, the paralysis will probably persist for the remainder of life. Unlike the hemiplegia of cerebral hemorrhage, the paralysis is not so apt to undergo slow but progressive improvement. Recovery takes place either rapidly or not at all in the large majority of cases.

The further course of the disease can be distinguished in no respect from that of cerebral hemorrhage. As we have stated in our discussion of the latter subject, even a post-mortem examination may fail to distinguish in old cases between the remains of a clot and an embolic process, inasmuch as the embolus itself may gradually have been absorbed and the original brain lesion replaced by a cyst or cicatrix.

For the changes in the symptomatology due to the varying location of the embolus, we must again refer the reader to the article by Dr. Starr, on *Brain Diseases: Diagnosis of Local Lesions.*

But we will here describe a very peculiar group of symptoms, apparently of bulbar origin, which has been observed in a number of instances in which the lesion was situated in another part of the brain. The clinical history of this form of disease is well shown by the following case reported by Berger:

"A man, aged sixty-one, suffering from small, contracted kidneys. In 1883 dysarthria and dysphagia developed suddenly without any violent apoplectiform symptoms. At the end of two days right hemiparesis and salivation were observed. Striking improvement after local faradization. About a year later an attack of tonic rigidity of the body, followed by an exacerbation of the disturbances of speech and deglutition, and also of the right hemiparesis. Paralysis of the orbicularis oris, particularly on the right side, and of the muscles of the tongue and deglutition. Inconstant condition of the glosso-labio-pharyngeal paralysis; no progressive course. No atrophy; normal electrical irritability of the paralyzed muscles."

Quite a number of autopsies have shown that symptoms of this character may be due to a bilateral or even unilateral lesion of the cerebral hemispheres in any position which interferes with conduction from the cortex to the centres of articulation and deglutition in the medulla oblongata, though the latter may be entirely intact. A case of this description, in which I was fortunate enough to obtain an autopsy, was seen by me only a few days ago. In this instance a spot of softening was situated in the anterior third of the posterior half of the right internal capsule, and also involved slightly the anterior part of the optic thalamus.

Diagnosis.—The diagnosis of cerebral embolism has been considered in part in the discussion of cerebral hemorrhage, so that very little need now be said on the subject.

One combination of symptoms, viz., the sudden occurrence of right hemiplegia and aphasia in a patient who has previously presented no cerebral symptoms, is extremely characteristic of embolism of the left middle cerebral artery. This group of symptoms is observed with comparative rarity as the result of any other lesion, though, of course, a hemorrhage occurring in the internal capsule may give rise to the same symptoms. In the latter event, however, the disturbance of consciousness is usually more severe than in the former, and, in addition, the onset of the disease is generally not so sudden.

The development, during an apoplectiform attack, of an embolism of the central artery of the retina is very significant of a similar affection of one of the cerebral vessels. Symptoms indicative of the formation of infarctions in the spleen, kidneys, and lungs may also aid us in coming to a conclusion.

Youthful age and the presence of valvular disease of the heart also point to embolism rather than hemorrhage. In very young children and infants, however, cerebral embolism is much rarer than hemorrhage.

If aphasia occurs as the sole symptom the diagnosis must be made from the attendant circumstances, such as the existence of cardiac disease, the occurrence of previous attacks of a clearer nature, the age of the patient, and the subsequent history of the disease.

Berger states that the pseudo-bulbar symptoms mentioned in the preceding section are distinguished from glosso-labio-pharyngeal paralysis by the following differential features:

1. Sudden apoplectiform development of the symptoms, which present no tendency to progression.
2. The presence of other cerebral disturbances.
3. The absence of atrophy of the paralyzed muscles, even after the disease has lasted a considerable time.
4. The absence of the reaction of degeneration.
5. The intact reflex irritability of the paralyzed muscles.
6. The absence of signs of progressive muscular atrophy.

Prognosis.—This depends mainly upon the situation and character of the artery—whether terminal or not—in which the embolus has lodged, and upon its complete or incomplete occlusion. The latter factor is of comparatively slight importance, since incompletely occluding emboli usually are converted into completely occluding ones from the secondary deposit of a thrombus. As a matter of course, the occlusion of one of the vessels supplying the pons or medulla may prove rapidly fatal.

If improvement occurs it usually takes place within one or two weeks. Otherwise the symptoms remain stationary or are complicated at a later period with secondary contractures, etc., as in cerebral hemorrhage. According to our experience, there is less danger of mental impairment than in cerebral hemorrhage. Relapses may occur at any time from the continuance of the primary cause. Death occurs much less frequently than in hemorrhage of the brain, unless the embolus lodges in the basilar artery.

CEREBRAL THROMBOSIS.—*Etiology.*—Thrombosis of the cerebral arteries is generally the result of atheromatous degeneration of the vessels. In such cases the current of blood is also usually slowed on account of weakness of the heart's action, and coagulation, therefore, takes place upon the roughened parts of the inner coat of the vessel. The deposit of coagulated blood gradually increases in extent until, as a rule, the lumen is entirely occluded. In rare instances, however, a parietal thrombus forms, leaving part of the lumen free for the passage of blood.

As we have stated previously, it is quite common to find, also, that a secondary thrombus is deposited upon a cerebral embolus, whatever the origin of the latter may have been.

A syphilitic affection of the walls of the vessels may lead to thrombosis in the same way that atheroma does, but the syphilitic vascular lesions have been discussed under a separate heading (see *Brain: Syphilis*).

As atheroma of the vessels is usually one of the accidents of advancing age, so thrombosis is also most frequent after middle life.

Another variety of cerebral thrombus is that known as the marasmic thrombus. This develops in intact vessels as the result of simple retardation of the current of blood (perhaps associated with a change in its chemical constitution), and is observed usually after protracted, exhausting diseases or severe attacks of an acute infectious disease. This variety is also observed in childhood, from similar causes.

Another form of thrombosis is the result of direct compression of the vessel, either from a mass of surrounding exudation, particularly in tuberculous meningitis, from the growth of a tuberculous new formation through the wall of the vessel, or from the pressure of a tumor of the brain. In such cases, however, the clinical history of the thrombus is usually lost in that of the primary disease.

Clinical History.—Cerebral thrombosis is frequently preceded by prodromal symptoms, which vary greatly in character and duration, lasting at times for many months. These symptoms are due probably to the impaired nutrition of the brain, on account of the slowly increasing diminution of the elasticity and calibre of the affected vessel.

Dizziness is one of the most common prodromal manifestations; it may be constant or intermittent, and is often aggravated by any sudden change in position. Violent headache is more infrequent, and is usually diffused over the entire head. The patient grows moody and morose, the memory is weakened, and impairment of speech may also be noticed. Sometimes intercurrent attacks occur, in which the individual partly loses consciousness, experiences numbness in an arm or leg, and, perhaps, has a slight loss of power in these parts.

In addition to the cases of mental weakness, Monakow describes a form of more decided psychical disturbance. This may assume the shape of senile mania or melancholia or the delusions of persecution. In the latter event, the patient believes himself ill-treated by his family and friends, threatens lawsuits in order to defend his rights, etc.

Others exhibit increased excitement, with vivid hallucinations and occasionally, as in ordinary acute mania, sing aloud, gesticulate violently, and exhibit complete confusion of ideas; destructiveness may also be manifested. This condition rapidly gives place, however, to a quiet dementia.

Melancholic conditions are rarer. They are characterized by mental confusion and depressive excitement; delusions of a religious tinge are sometimes noticed, and there may be a tendency to suicide. This condition also terminates quickly in dementia.

After a longer or shorter duration of the prodromal stage, the symptoms proper of the thrombosis usually develop with great rapidity. Sometimes, indeed, the attack is as sudden as one caused by embolism or hemorrhage, and if no previous symptoms have been observed, it may be impossible to make a differential diagnosis. The symptoms of the attack itself can usually be distinguished in no respect from those of cerebral hemorrhage, but there is some difference to be noted in the subsequent history. Recovery from the paralysis which has been produced is extremely exceptional. On the contrary, the impairment of motion grows more marked with time. This feature is explained in part by another peculiarity of the affection, viz., that very commonly the mental power becomes steadily impaired after the attack of paralysis. If several seizures occur (as is not infrequently the case), the patient gradually sinks into a condition in which he forgets almost everything, and even fails to attend to the wants of nature; his speech is thick and indistinct, etc.

The symptoms due to thrombosis of the basilar artery are so peculiar that they merit separate consideration.

The symptoms develop suddenly or gradually, according to the mode of development of the thrombus.

Sometimes merely a severe apoplectic attack is produced, accompanied often by contraction of the pupils and irregular breathing, the attack proving fatal in a period varying from a few hours to several days.

But usually very characteristic phenomena are developed. If hemiplegia is present (and this is usually the case), it is generally of the so-called "alternate" type (Gubler). In this form of hemiplegia the body is paralyzed on one side and the face on the opposite side (the paralysis of the facial nerve involves the occipito-frontalis and orbicularis palpebrarum, and is therefore similar to peripheral facial paralysis). In addition, there is another very rare form of alternate hemiplegia, in which the face and body are paralyzed on the same side, the motor oculi communis on the opposite side. Leyden proposes to call the former variety inferior alternate hemiplegia, the latter variety superior alternate hemiplegia.

In addition, disturbances of speech and deglutition are frequently produced, the former more commonly than the latter. The difficulty of speech is shown by the thick, muffled articulation, and is due to paresis of the muscles of articulation; in other words, it does not present the characteristics of any of the forms of aphasia. The tongue is usually moved with difficulty. The bodily temperature is apt to rise very high in these cases shortly before death, and Eichhorst has reported a case in which the temperature reached 108° F.

Despite the gravity of the lesion, some patients make a tolerably complete recovery, and again become able to walk about, until a further extension of the disease produces a second and fatal attack.

Diagnosis.—As we have on several occasions remarked, the symptoms of an apoplectic seizure due to cerebral hemorrhage, embolism, and thrombosis may be identical. But the attendant circumstances are often of such a nature that we shall be enabled to distinguish cerebral thrombosis from the two other affections mentioned.

When the prodromal stage is very long and the attack itself develops slowly, the recognition of thrombosis is usually quite easy. But when these conditions do not hold, the diagnosis depends chiefly upon the age of the patient, the condition of the blood-vessels (particularly the radial and temporal arteries), and the subsequent history of the case.

Furthermore, it is characteristic of this disease that it is very often attended by a gradual, pronounced failure of the mental powers, so that the patients finally sink into a demented condition.

In a considerable proportion of cases, however, it is impossible to make a positive diagnosis between cerebral hemorrhage and thrombosis.

Prognosis.—The prognosis, as regards complete recovery, is extremely unfavorable, not so much on account of the severity of the lesion itself, but from the fact that the vital powers are usually at such a low ebb that restoration of function in the affected parts is impossible.

Sometimes a considerable interval elapses between the individual attacks, but the disease is always progressive, and unless carried off by an intercurrent disease, the patient gradually sinks into a condition of imbecility, finally gets up bed-sores, etc.

Treatment.—During attacks of cerebral embolism or thrombosis very little can be done beyond keeping the patient perfectly quiet. When indicated by the pulse, stimulants should be administered to rouse the failing action of the heart.

After the primary attack has passed over, the treatment of the residua of embolism will be essentially the same as that advised concerning cerebral hemorrhage.

After thrombosis, the paralysis and other symptoms do not yield to treatment, and little can be done beyond keeping up the general nutrition of the patient.

Leopold Putzel.

BRAIN: FUNCTIONS OF CEREBRAL CORTEX.— It is now conceded that the physiological processes underlying sensation and perception, emotional expression, language, voluntary movement, memory, the association of ideas and intellection are to be sought within the encephalon. It is admitted, also, that the structures which are thus prerequisite to every manifestation of mental life are the neurones of the cortex of the cerebral hemispheres. Exner's statement that a "physiology of the cerebral cortex in the sense in which there is a physiology of the muscle, etc., scarcely exists at the present time" is doubtless as true now as it was two decades ago. And yet the functions of the cerebral cortex, both of its entirety and also of differentiated portions, are at the present day in large measure ascertained and comprehended.

A bare recital of the facts of cerebral localization conduces only to confusion. It would be difficult to point to another department of science in which facts as facts have so little significance. Before a fact or reputed fact can be comprehended and made to serve as the basis for conclusions concerning the nature and localization of the cerebral functions, it must not only be critically examined on its own merits; it must also be connected with a great multitude of other complicated phenomena and interpreted in relation to general theories of mental and neural activity. The comprehension of the functions of the cerebral cortex is mainly the result of psychological interpretation and analysis.

Six different methods of investigation or lines of inquiry have contributed all the facts upon which the conclusions that constitute the science of cortical neurology are based. Each has certain advantages not possessed by others, and each has its limitations. The first of these methods is the *method of biological comparison*. Although this is the oldest method, it is certainly the least important. Even the ancients had noted the greater size of the human brain in comparison with that of the lower animals, as well as the more complicated structure of its convolutions; in consequence, some taught that the superior intelligence of man was to be accounted for by the greater size of his brain, and that the brain was peculiarly the seat of intelligence. It has been customary, also, to compare the size of the frontal lobes in the more intelligent races with that of the same structures in the less intelligent races and in the lower animals. But this method alone would lead to the conclusion that the occipital and perhaps the temporal lobes were also the seat of higher psychical processes. Attempts have been made to draw positive conclusions from examination of the relative size, weight, thickness, and surface area of the cerebral convolutions in normal and degenerate individuals or classes of men. This method furnishes only presumptive evidence that relative excess of cortical substance is associated with higher grades of intelligence.

The second method is that of *experimental extirpation*. This method was the first to give convincing evidence of diversity in the localization of functions within the cerebro-spinal nervous system. Observations on the brainless frog revealed the significant difference between those functions which could be carried on by the spinal cord alone and those which required the spinal cord and brain. The distinction between a reflex and a conscious reaction was thus no longer a matter of definition, for the brainless frog was shown to be a simpler, more mechanical, and less intelligent frog than the intact frog. The differentiation between sensory and motor paths of conduction, first demonstrated by Bell through sectioning of the ventral and dorsal nerve roots, next revealed the possibilities of artificial interference or extirpation. Increased refinement of procedure has made possible the destruction of small or large portions of the cerebrum for the purpose of observing the resultant effect upon the behavior of the animal after recovery. The interpretation of the results of small or large ablations is beset with many difficulties. It is therefore not surprising that different observers have obtained widely divergent results. If the effect of experimental extirpation be restricted to paralysis of a group of muscles or to some disorder of motility, and if these disturbances persist long after the operation, the inference is relatively direct. But after ablations that affect sensation only, the exact amount and character of the sensory disturbance is sometimes difficult to ascertain, because these experiments are necessarily restricted to the lower animals, and the loss of sensation must be inferred from disorders of movement functionally related to the sense in question. Moreover, it is not easy even with the most approved method to limit the area destroyed. Inflammations ensue, degenerations take place, cicatrices and abscesses may form. Post-mortem examination will not always serve convincingly to distinguish areas that have been rendered functionless from those that were still active at the time of death. Many of the phenomena of motor and sensory disturbance are evanescent, while others are so minute as to escape all but the most careful observation. Paralyses which slowly recover may be explained either by assuming an identity of function for different portions of the cortex or by a substitution of function on the part of cells that have learned to perform an unwonted task. To distinguish between a simple loss of sensation and those losses which have been variously described as soul-blindness, soul-deafness, etc., is a matter of extreme difficulty. The exact nature of the details of the psychical life of the lower animals is wholly conjectural; anatomical homologies between the human brain and the brains of lower animals are of doubtful significance, and it may be questioned whether anatomically identical parts of the brains of man and the lower animals perform similar functions. It is, therefore, not surprising that the functions of the frontal lobes were first unassailably established by this method only within the last decade through the painstaking experiments of Bianchi.

The *pathological method*, which may also be called the method of natural extirpation, has peculiar advantages. The subjects of such experiments of nature are human beings, who may be carefully studied and questioned. The post-mortem location of cerebral lesions has been of the greatest service in furnishing early and convincing evidence of cortical areas of specific function in the human brain. The existence and location of a speech centre was demonstrated by Broca from pathological findings as early as 1861 and was suggested by Bouillaud even in 1825. The evidence furnished by the pathological method is, however, often equivocal and even contradictory. The morbid anatomy of the brain is vague and indecisive compared with the definiteness of many established forms of mental disease. Conflicting evidence is to be expected. Cerebral lesions are seldom circumscribed; tumors or hemorrhages at any one point often produce associated and secondary functional disturbances which may obscure the exact relations of cause and effect. It is also very seldom that bilaterally symmetrical lesions occur; and yet these are in some cases the only cause of the complete and persistent loss of function. Moreover, observers have not until recently determined and reported the ante-mortem condition of the patient with sufficient regard for essential details. To this lack of careful observation chiefly is ascribable the tenacity of the belief in the existence of so-called "silent areas."

The *method of irritation* (chiefly electrical irritation) has contributed materially to the exact localization of cortical centres for the various bodily movements. By this method very small areas are incited to functional activity either by the electric current or by mechanical or chemical irritation. An objection to the localization of centres in the cortex by direct stimulation of the gray matter of the cerebral hemispheres has been found in the fact of electrical diffusion through the substance of the brain, whereby even weak currents may act upon areas remote from the electrode. Even the separation of the mass of a particular area by section from adjacent parts will not eliminate the diffusion of the current through the blood or along the nerves of the normal pathway of projection. Although it had been established that a current will produce similar movements whether applied to the gray matter of the cortex or to the fibres immediately below, Franck and Pitres and Carville found that when applied to the cortex the current may be weaker and that the movements follow the application of the stimulus at an appreciably greater interval. These results demonstrate the participation of the gray matter of the cortex in the production of the movements. The epoch-making investigations of Fritsch and Hitzig advanced conclusive evidence that movements of greater co-ordination can be produced by the application of currents to restricted areas of the Rolandic cortex than by stimulation elsewhere. The method of irritation has been employed chiefly on the lower animals, but occasionally also upon man.

The *histogenetic method*, more familiarly known as the embryological or myelinization method, which is the outgrowth of modern improvements in histological technique, has, in the hands especially of Meynert, Edinger, and Flechsig, contributed results of great value. This method seeks to establish the anatomical relations of conduction pathways and cerebral centres at ontogenetic periods before the number and complexity of interlacing fibres defy the analysis of the microscope. The projection and other fibres of the cerebral cortex take on their myelin sheaths at different periods of fœtal and infantile life; before their myelinization they are believed to be functionless. The maturity of the cortical areas to which these fibre tracts belong may be inferred, according to Flechsig, from the successive development of the tracts themselves.

The last method to receive mention is the *histo-degenerative method.* Secondary degeneration of nerve fibres and tracts invariably follows artificial extirpation and natural lesions. This degeneration is at first always in the direction of the functional conductivity of the tract; but later degeneration is also observed in the contrary direction toward the centre of neural emission. The study of the course of such degenerations has supplied much new evidence pointing to the anatomical and physiological connection of cortical areas with lower centres. The histological methods may be expected to supply in the future the more valuable contributions toward the comprehension of the interrelations of the neuronal elements of the various parts of the cerebral cortex.

These various methods have contributed within the present century a mass of material evidence, the several details of which are often self-contradictory, but from which a consistent consensus of opinion can be gathered by critical sifting and weighing of opposing contentions. The present article attempts to present only the general tendencies of the results and to outline the more significant conclusions. The over-emphasis of conflicting details and of erroneous interpretations of results has often caused the localization of specific cerebral functions to appear more doubtful than it really is. The psychological and metaphysical theories, which have helped to form the opinions of physiologists and other investigators, have contributed not a little to this confusion. Physiologists, in revolt against the dogmatism of metaphysical speculation, have frequently sought to frame conclusions in such manner as to avoid entanglement with psychological theory. The result, unexpected by them, has often been to warp or pervert their conclusions by primitive psychological points of view, which had long before been discarded even by traditional psychology. The controversy of Pflüger with Lotze is a notable illustration of this tendency of the physiological mind to assail certain doubtless unjustifiable psychological theorizing, and yet, in the effort, reverting to a speculative attitude that the history of the development of the anatomy and physiology of the nervous system shows to have been a distinguishing characteristic of the science only at its earliest beginnings and to have long since been set aside. Speculative views on the nature of the human soul or mind and on its relation to the body and objects of nature have always determined the trend of conclusions respecting the specific functions of the cerebral cortex; for the reason, as has been before maintained, that these conclusions are necessarily psycho-physiological inferences.

Until the time of Descartes all interpretations of physiological functioning were based upon crude psycho-physiological theories which were the outgrowth of a notion variously described as *animism*, *vitalism*, and *anthropomorphism.* Briefly, animism identifies consciousness, life, and movement. The soul may be identified with the breath, because with the cessation of breathing the life and soul of the organism cease to exist or at least leave the body. Other observers, their attention attracted to the movement of the heart as the most significant bodily function, assumed this organ to be the seat of life and consciousness. Thus Aristotle considered the brain the coldest and most bloodless of the organs, its chief purpose being to temper the excessive heat of the heart, the true organ of the mind. Though the soul, as the vital principle of the entire organism, may be connected more particularly with some one organ of the body, nevertheless every organ, and indeed every object of nature, according to the animistic doctrine, functions through its endowment with a conscious vitalizing principle. Every physiological process and certainly every bodily movement is, from this point of view, the work of a rational and intelligent, though not always conscious or reflective spirit or soul. The animistic hypothesis is one that appears throughout the history of the organic sciences in many different guises. It is the progenitor of the doctrine of animal or vital spirits, and at almost all periods has inspired theories of psycho-physiological generalization such, *e.g.*, as that advocated by Pflüger as late as the middle of this century.

It must not, therefore, be supposed because Pythagoras maintained the brain to be the seat of the mind and intellect and Hippocrates speaks of the brain as the index and messenger of the intellect that they had arrived at these conclusions from a careful observation of facts. These are rather lucky guesses which subsequent research substantiated. Doubtless a few had observed the effect of concussion of the brain and had even referred idiocy to brain deficiency. It is stated that Hippocrates commented upon the loss of mental function following disease and injury of the brain, and that Polybos claimed the brain to be a centre for the nerves and the organ of the mind. Erasistratus is said to have taught that sensory nerves arise from the brain membranes and motor nerves from the cerebral substance. Herophilus, according to Celsus, maintained that vital forces resided in and circulated from the ventricles of the brain, and Galen stated definitely that the seat of the soul and intellect is in the brain and that the animal spirits have their origin in the ventricles of the brain and pass thence to the heart through the arteries. The Christian writers adopted Galen's view and conferred on it a theologic sanction which made correction difficult. As late as the thirteenth century Gordon, professor of medicine in Montpellier, placed common sensation and the reception of impressions in the anterior cornua of the lateral ventricles, imagination and intellection in the posterior, judgment in the third ventricle, and memory in the fourth. Rhazes (1554) localizes imagination in the second lateral ventricle, reason in the middle ventricle, and memory in the posterior. Willis (1622–1675) considered the brain substance as the dynamic source or storehouse of the animal spirits. He placed memory and will on the convoluted surface of the cerebrum, and associated imagination with the corpus callosum, sense perception with the corpus striatum, impulse and emotion with the basal parts about the crura, vision with the thalamus, and involuntary acts with the cerebellum. These somewhat suggestive attempts to state the psycho-physiological functions of the brain were rendered futile and bereft of all inspiration to experimental discovery by the persistent belief in the doctrine of animal spirits. When some anatomists of the seventeenth century attacked vital spirits resident in the ventricles (Alexander Benedictis as early as 1527 was so bold as to doubt that the spirits existed at all), they were regarded as revolutionary by the great majority of the seventeenth and eighteenth century medical writers. The vital spirits, however, were gradually losing their psychical attributes and were at this time generally defined as like to "little flames" or in a still more material way as those "very subtle particles" (Willis). Moreover, anatomical investigations were indicating the nerves rather than the arteries as the conductors of these animal spirits.

Descartes (1596–1650) first presented a psycho-physiological theory which contained possibilities for future advance. With him began a new era in physiological speculation. His chief contributions were (1) a consistent theory of a sensorimotor mechanism; (2) a clear distinction between the automatic or reflex functions of the cerebro-spinal system and its conscious functions; (3) a description of the sensorimotor arc as composed of afferent and efferent nerves and of a central system capable of reflecting sensory impulses from the brain to motor nerves mechanically and unconsciously, or even in spite of the will. Although it cannot be claimed that Descartes discovered spinal reflexes, for he considered the brain as the centre for both conscious and reflex movements, he nevertheless was far ahead of his time in justly appreciating the reflex capacity of the central nervous mechanism. He made the error of assuming that there must be a single point in the brain at which sensory impulses are transformed into sensations and the will exercises its determining influence upon the body. Even those who scorn this philosopher's attempt to find the seat of the soul in the pineal gland are not seldom guilty of a similar assumption, although they may perhaps assign it a different location.

After the time of Descartes various observers soon began to report reflex phenomena, but it was not until a century had passed that Whytt (1714–1766), in an essay on "Vital and Other Involuntary Motions of Animals," reported the now classical experiment of Hales. A decapitated frog was shown to be capable of reflex movement for thirty hours after decapitation. When a needle was thrust down the spinal marrow, the animal was strongly convulsed and immediately afterward became motionless. Whytt concludes that the immediate cause of the contraction of the muscles of animals, or at least a necessary condition, is a certain power or influence lodged in the brain, spinal marrow, and nerves. Of this power he says: "If in compliance with custom I shall at any time give it the name of animal or vital spirits I desire it to be understood to be without any view of ascertaining its particular nature or manner of acting." Whytt demonstrated the special structures with which reflex functioning is connected. He believed, however, that no motion could take place in the body unattended by some degree of consciousness, thus rejecting the mechanical theory of Descartes and substituting a diffusion of consciousness wherever nerves are found.

Whytt's definition of the "power of nerves" was fixed for science by Haller (1708–1777), who maintained the existence of a similar power inherent in living muscle. This he called irritability or "vis in situ," which he considered to be independent of the sensibility of nerves. He also used the term "vis nervosa," but nevertheless takes for granted the existence of animal spirits and even debates what manner of fluid it may be.

The development of the concept of a force of gravity and the exploitation of the famous vibration theory of Newton made possible a detailed development of the mechanical theory of nervous reaction suggested by Descartes. Thus David Hartley (1649), the well-known psychologist, endeavored to explain the functions of the brain in connection with the association of ideas and sensations on a basis of the vibrations of the ether, a subtle fluid of the nerves. Indeed, Newton had himself, in the "Principia," advanced the opinion that all sensations and movements are excited by the vibrations of a very subtle spirit propagated through the solid capillamenta of the nerves from the organs of sense to the brain and from the brain to the muscles.

Unzer (1727–1799), taking up Whytt's results and point of view, distinguished more clearly between the sensory impulse which travels from the periphery to the brain, and the material idea, as he calls it, into which it is transformed in the brain, giving rise to an image in the soul. The sensory impulse on reaching the brain is reflected or turned back, giving rise to motion with conciousness. If it is reflected or turned back before reaching the brain it gives rise to motion without consciousness. Unzer, however, thought that the spinal ganglia were the structures in which this reflection took place.

Prochaska's work on reflex action (1749–1820) remained for fifty years an object of commendation. He was looked upon by Longet as the investigator who first made reflexes a distinct class of action. He clearly posited a vis nervosa as the cause latent in the nervous pulp, capable of producing certain effects when acted upon by a stimulus. "External impressions made on sensitive nerves are propagated with great velocity throughout their entire length to their origin. From this place, they are reflected according to a certain law and pass into certain and corresponding motor nerves by which again, being very quickly propagated to muscles, they excite certain and determinate movements. This place in which, as a centre, nerves of sense and motion meet and communicate, and in which the impressions of sensitive nerves are reflected into motor nerves, is called by a term already received by most physiologists, the 'sensorium commune.'" Prochaska even brought his central mechanism into line with biological conceptions of instinct, in maintaining that the law under which reflection takes place is "the preservation of the individual." Many physiologists had followed Newton in establishing a vibration theory for the nervous system; Prochaska, in turn, was influenced by Galvani's discoveries to look upon electricity as the physical condition for the manifestation of vis nervosa. Neither Prochaska nor Unzer made any lasting contribution to our knowledge of the localization of diverse centres of reflex and conscious reactions.

Unzer had presented certain views on the localization of cerebral functions, and Prochaska in 1784 published in Vienna a work on the nervous system in which he developed a scheme of cerebral localization which establishes him as the immediate predecessor of Gall. Owing to the unproductiveness of the phrenologists and because of the dogmatism with which the system was asserted, it is customary to look upon Gall as having no place whatever in the development of the science of neurology. The excesses of phrenology are to be attributed to Spurzheim, Combe, and their followers. Their noisy advocacy of what they considered a philosophical system gave to it great popularity until the middle of this century, and its attendant ill-repute in scientific circles. Gall, it is true, embraces within his system the views of the physiognomists, who had remained somewhat outside the pale of science; but he is nevertheless a legitimate successor of the cerebrationists of his time. The advanced position which he held and the discussion to which it gave rise were a distinct impulse to the development of experimental work in neurology. Indeed, Gall and Spurzheim were among the first to give public demonstrations of the anatomy of the human brain, as also they were among the first to advocate that the cerebral cortex is the only organ of the mind. It is true that Gall and his followers contributed nothing to our knowledge of the localization of functions in the cerebral cortex, but they nevertheless pointed the way; those who followed, employing more legitimate scientific methods, initiated the discoveries that have led to the present status of the science. Gall's methods hark back to preceding modes of thought and demonstration, and hence he is the last significant figure of a line of speculators and investigators that began with Descartes. After him, the presumption has always been in favor of specialization of function, and of restricting the psychical functions of the nervous system at least to the cerebrum. His chief errors flowed from the acceptance of a psychological system, which viewed the mind as made up of separate faculties, and from his readiness to use insufficient evidence to arrive at far-reaching conclusions. Thus he placed the faculty of language behind the eyes, because he observed the protruding eyes of some of his school-fellows noted for their facility in language. The protrusion of the eyes and the various bumps upon the skull were to him indices of the growth of the convolutions immediately beneath. Gall recognized twenty-six different faculties or organs, and selected their place by examining the heads of friends, of inmates of jails and lunatic asylums, and of other persons who happened to be conspicuous for some special faculty or mental trait. These twenty-six organs were marked upon the skull by round enclosures with vacant interspaces. The common phrenological charts wherein the skull-cap is portrayed divided into oblate and coterminous areas are the production of Spurzheim and Combe, who increased the number of faculties to thirty-five and neatly filled out the entire area with an equivalent number of organs.

When Bell, in 1811, published the results of sectioning the anterior and posterior roots of the spinal nerves, he gave to the world the first satisfactory demonstration of the specificity of the function of motor and sensory nerves. He thereby initiated the era of experimental investigation and laid the foundation of modern nerve physiology. Simple as were the facts observed by Bell and clear as was the evidence, the embodiment of his results, known as Bell's law, was not accepted without challenge. On the one hand, he was accused of dissecting the brain to find the seat of the soul. It was probably for this reason that he privately published his conclusions in a communication entitled "Idea of the New Anatomy of the Brain, Submitted for the Observation of His Friends." On the other hand, it was argued against Bell's law that the mechanical juxtaposition of fibres of specifically different function was as unscientific as the system of phrenology. As late as 1831 Lange and Beck maintained that Bell's law was as speculative as Gall's localization of cerebral functions. The labors of Magendie, Bellingeri, Panizza, and Van Deen confirmed Bell's conclusions. Müller's "Physiologie" (1834) established Bell's law in Germany, contributing to the facts of functional specificity by the galvanic irritation of both roots of the spinal nerves of the frog. Longet, in 1841, demonstrated Bell's law on higher animals.

Before the relation of the sensory and motor roots to the gray matter of the cord and cerebrum could be established, some intelligible hypothesis was necessary to explain the function of the cord in transferring a sensory stimulus to a motor nerve. Marshall Hall's "Memoirs on the Nervous System" (1837) elaborated a mechanical theory of reflex action. He maintained that the cord is composed of two parts very closely connected with each other; the first part is a bundle of nerves mediating sensation and volition, the central organ for these fibres being in the brain; the second part is the true spinal cord, generally though not invariably connected with the first part and distinguished by excito-motor nerves. He thus assumed the existence of two separate systems of nerves, an excito-motor system and a sensori-volitional system, both perhaps enclosed within the same nerve sheath. With the function of the excito-motor system nothing psychical was associated; he stoutly affirmed that brainless reflexes were unattended by sensation or by any other rudimentary form of consciousness even in the least degree. The excito-motor force he identified with Haller's vis nervosa, Müller's motor power, and Flourens' excitability. Kürschner, who translated Hall's work into German, maintained that sensory nerves ran in the posterior column and motor nerves in the anterior column. He distinguished single movements of flexion and extension that are produced in the cord from the coordinate movement of limbs produced in the cerebellum and cerebrum.

Many observations were made to determine the truth of Hall's statement that brainless animals never moved spontaneously. Volkmann, in Müller's *Archiv* for 1838, justly maintains that whether the cord has obscure sensations is not manifest, for experiments prove only that the part of the body furnished with a brain does not feel the irritation of that part which has been severed from its connection. He inclines to the view that the behavior of animals with cord and oblongata is not purely reflex, but rather of such character that it is impossible to deny the co-operation of a psychic principle, the degree of consciousness in such case being dreamlike, and marked by the presence of obtuse sensations and even obscure conceptions that help to determine the movements. Müller, on the other hand, maintained that if the sensory stimulus can pass on to the sensorium commune in the brain, it becomes a conscious sensation, but in case of section of the spinal cord it produces centripetal action in the cord only. In both cases reflex movements may result, but in one instance they are attended by conscious sensation, in the other not.

The last opponent to the theory of non-conscious spinal reflexes and of the localization of all psychical functions within the cerebrum was Pflüger (1853), who contributed so largely to our knowledge of reflexes and yet vitiated his conclusions with primitive metaphysical considerations. Consciousness for him is motion and exists wherever central nerve substance is found. It is divisible in all animals with its material substratum; hence the well known theory of a spinal-cord soul. Reflex action is the operation of a neuro-psychic mechanism by means of which the peripheral sensory fibre, by whatever cause excited, causes through mediation of the spinal cord the ordinary state of excitation in motor nerves. The brain is not the only organ of sensation; the functions of the sensorium are extended throughout the cerebro-spinal system.

A consistent theory of the central neural mechanism was finally contributed in an acceptable form by Lotze in the article on "Instinct" in Wagner's "Handwörterbuch der Physiologie." He suggests that the reflexes, and probably the lower instincts also, are purely mechanical. These elementary reactions, he explains, are due to purely physical connections which have been established by nature, and which the mind can neither invent nor construct. After the mind learns these elementary movements, it may weave them into richer and more complicated patterns, just as letters may be combined by the mind into sentences. Physical changes set up in the peripheral ends of sensory nerves are therefore conducted unaltered in character to the brain. Here occur all those processes by which physical excitation is transmuted into the psychic forms of sensation, feeling, etc. The reflexes of Pflüger's decapitated frog are due not to sensation or intelligence present in the cord, but to the after-effects of these, for the motor states of the mind are transformed into nervous impulses in the brain alone, whence they are propagated through the efferent nerves to the muscles. By practice and training a secondary character which survives decapitation is imparted to subordinate centres. Lotze's mechanism is thus constituted of inherited and acquired habits. With Lotze's explanation of the neural basis of reflex, instinctive, and conscious reactions, the restriction of strictly psychical functions, at least, to the encephalon may be considered to have been at last decisively established.

Meanwhile, the evidence of the specificity of parts of the encephalon was being advanced by experimental physiologists in the first instance and by pathologists in the next. Flourens, in 1821, published his "Experimental Researches on the Character and Functions of the Nervous System"; a second edition in 1842 reported additional experiments. Longet and Vulpian, in 1866, and Goltz, in 1869, contributed experimental evidence. Flourens was the first to employ extensive ablations of various portions of the encephalic nervous system. He was thus able to locate a centre for the coordination of respiratory movements near the angle of the calamus scriptorius and to show that the medulla oblongata contained centres for movement of the face and for some forms of emotional expression. Vulpian demonstrated that a young rat deprived of all the encephalon above the medulla oblongata can yet move its limbs and emit a cry of pain when its toes are pinched. On destruction of the oblongata the cry ceases, but the reflex movements continue. Moreover, he correctly interpreted the cry as no real sign of pain, but only a reflex contraction of the laryngeal and expiratory muscles. The investigations of Flourens in 1828, and later of Goltz, proved that the semicircular canals are the peripheral organs of equilibration, and located the central organ of equilibration in the cerebellum. These demonstrations were made on pigeons, cats, dogs, and moles. In all cases, partial ablation of the cerebellum induced disturbances of gait and station, ranging from slight swaying or reeling to an apparently complete loss of station and locomotion. Similar experiments performed on the cerebral hemispheres seemed to show annihilation of perception, ideation, volition, and intelligence in general, but large tracts of the brain cortex could, according to Flourens, be removed without causing any apparent mental disturbance. The ablation of single areas produced a similar result. These results led Flourens to the formulation of the dictum of the equivalence of all parts of the cerebral hemispheres, each portion being capable of performing all the functions of the whole. Flourens believed, however, that sensation proper was destroyed by removal of the cerebral hemispheres. Vulpian, on the other hand, maintained that sensation continued, but was crude and obscure in comparison with the distinct sensation or perception of the cerebral hemispheres. Longet ascribed the crude sensation to the midbrain. Goltz does not decide the question, but ascribes to the midbrain an adaptive faculty and terms the reactive functions of these centres, "responsive" movements. Ferrier accepted this distinction and suggested three groups of reactive functions: the kentro-kinetic or excito-motor function of the spinal cord; the æsthetico kinetic function of the mid brain and cerebellum; and the noetico-kinetic function of the cerebral hemispheres. In this way, he endeavors to avoid the use of the term sensation in connection with the complicated movements of the midbrain, defining the æsthetico-kinetic reaction as one unaccompanied by consciousness. The various investigations of this initial period of physiological experimentation tended, when the results were analyzed and judiciously interpreted, to restrict all conscious functioning to the cortex of the cerebral hemispheres.

Flourens' researches had been indeed epoch-making, so far as they concerned the establishment of the specific capacities of the portions of the nervous system below the cerebral hemispheres. So thoroughgoing were his methods, so painstaking his researches, and so full of insight his conclusions, that the doctrine of the equivalence of all portions of the cerebral hemispheres long held sway, even against sound pathological evidence, and according to Ferrier became in consequence answerable for many erroneous notions in cerebral physiology and pathology. Schiff went so far in advocacy of Flourens' conclusions that he set aside the testimony of pathologists, which made for the specificity of parts of the cerebral hemispheres, as the opinions of "mere practical physicians." Those who localized specific areas over the cerebral convolutions were also often slightingly referred to as phrenologists.

And yet sound pathological evidence had steadily been accumulating which pointed to this specialization of cerebral function. Bouillaud, in 1825, from experiments on animals and from the facts of clinical research, was led to maintain that lesion of the anterior lobes was more particularly responsible for loss of speech, and that special motor centres are situated in the cerebrum, the destruction of which is responsible for paralysis. Limited lesions of the cerebral hemispheres, he reports, give rise to limited paralysis which would not be the case if the cerebral hemispheres did not contain a multiplicity of differentiated centres for the conduction of motor impulses. With prophetic insight he remarks: "I am well aware that the preceding propositions appear at variance with the results of experiments upon animals. It is certain that after ablation of the cerebral hemispheres an animal may walk, run, move its jaws, eyes, eyelids, etc.; and it is not less certain that an alteration of the cerebral hemisphere in man gives rise to paralysis, more or less complete, of voluntary motion on the opposite side of the body. Can we refute the one set of facts by the other? No, certainly not, for facts equally positive are not susceptible of refutation. A time will come when new light will dispel the apparent contradiction which exists between them."

The credit of having first indicated the motor function of certain regions of the cortex, and of giving a rational explanation of the phenomena of unilateral cerebral convulsions, belongs to Hughlings Jackson. Experimental physiology had apparently demonstrated that neither electricity nor any other customary stimulus of nerves and nerve centres was capable of exciting movement when applied directly to the surface of the brain. It was, therefore, inferred that centres below the cerebral hemispheres were alone capable of initiating movements, and that the cerebral convolutions exercised restrictedly a psychical function. Against this view, Jackson contended that the cortex did not transmit an "influence" to some distant motor region, but was itself motor and capable of motor discharge by irritation.

A much more dramatic discovery added force to the arguments of those who opposed the finality of the conclusions of the experimental physiologists. This was a contribution to the pathology of the cerebral hemispheres presented by Broca in 1861 and followed by corroborative evidence presented in a second contribution in 1865. In these clinico-pathological observations, Broca demonstrated that the cause of the disorder of speech known as aphasia, which had previously been symptomatically investigated by Lordat as early as 1820, Bouillaud (1825), Jackson (1829), Dax (1836), and others, was a lesion of the posterior third of the inferior frontal convolution. Analysis of the two cases first reported by Broca showed the lesion to be in the left cerebral hemisphere, which he at first regarded as accidental. Reports of similar cases by Voissan (1862), Broca (1864), and Seguin (1867), who had collected two hundred and seventy-two cases of right hemiplegia with aphasia, led to the conclusion that the speech centre was located in the inferior frontal convolution of the left hemisphere only. Broca himself, an anthropologist of note, offered, as an explanation, the fact that the great majority of humanity are right-handed, in consequence of which the left hemisphere contains the centres for the exquisitely coordinated movements which subserve speech, as well as those for the finer adjustments of movements executed by the more motile hand. Bastian (1869) was the first to recognize the relationship of defective auditory perception to speech production. Ogle (1871) distinguished aphasia from agraphia. Broadbent first pointed out in 1872 the condition which is known as "word-blindness." The investigations of Wernicke, which began in 1874, furnished the basis for the conception of sensory aphasia, and for the recognition of three varieties of aphasia: visual, auditory, and motor. He showed that a lesion of the first temporal convolution produced auditory aphasia, and maintained that the most typical aphasia can occur with lesion of other parts of the brain than Broca's convolution. Contributions of importance, leading on to a better understanding of aphasia, were made by Trousseau and Hughlings Jackson. Finally, Kussmaul, in 1877, in the article on Aphasia in "Ziemssen's Encyclopedia," introduced the terms "word-deafness" and "word-blindness," and fixed the concept of aphasia in a form which it retained substantially until the time of Déjerine.

About this time Fritsch and Hitzig, in 1870, changed entirely the attitude of experimental physiologists by their discovery that the application of the galvanic current to the cerebral surface of the brain of dogs gave rise to movements on the opposite side of the body. The result of these investigations was to show that certain portions of the convexity of the cerebrum are motor, while other portions are non-motor. The original experiments located five motor areas in the cerebrum of the dog: a centre for the muscles of the neck in the middle of the prefrontal gyrus at the place where its surface falls off steep, a centre for the extensor and adductor of the fore limb at the outermost end of the postfrontal gyrus in the region near the end of the frontal fissure; a centre for the bending and rotation of the same limb a little farther back; a centre for the hind limb in the postfrontal gyrus, but toward the median line of the hemisphere and back of the preceding two centres; and a facial centre in the middle part of the gyrus lying above the fissure of Sylvius (see Fig. 892). Points lying between these, when stimulated, produced contractions of the muscles of the back, tail, and abdomen, but circumscribed areas for these muscles could not be ascertained. The motor areas lie, therefore, to the front and the nonmotor areas behind. By using weak currents, the movements are localized to definite groups of muscles of the opposite side of the body, while stronger currents ap-

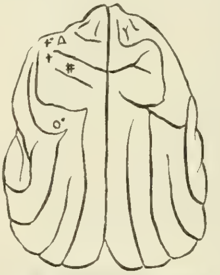

FIG. 892.—Cortical Areas in the Dog. (After Fritsch and Hitzig.) Δ, Muscles of the neck; +˙, extension and adduction of the fore-limb; +, flexion and rotation of fore-limb, #, hind-limb; O˙, facial area.

plied to the same or closely adjoining areas stimulate other muscles or even muscles of the same side. When the left cortical centre for the fore limb was excised, there followed a clumsiness of the right fore limb, the right foot (but never the left) easily slipping. Although no movement was quite destroyed, the right foot was adducted somewhat weakly and was often planted on the back instead of on the sole. Sensibility of the skin was not noticeably changed. These and later experiments substantiated the conclusion of the investigators that certain motor functions, probably all, are to be assigned to circumscribed areas of the cortex.

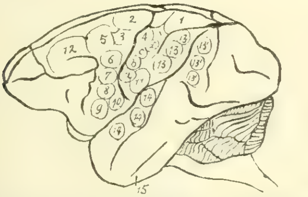

FIG. 893. Cortical Areas in Monkey. (Ferrier.) 1. Forward movement of leg; 2, the same, and toward middle line of body; 3, the same, with movement of the tail; 4, retraction and adduction of arm; 5, extension of arm; *a, b, c, d*, movements of fingers; 6, flexion and supination of arm; 7, lifting and retraction of angle of mouth; lifting of upper and sinking of lower lip; 9, opening of mouth, with protruding of tongue; 10, the same, with retraction of tongue; 11, retraction of angle of mouth and turning of head away from stimulated side; 12, opening of eyes, dilatation of pupils, head and eyes turned away from stimulated side; 13, turning eyes away from stimulated side and down; 13′, the same, and up; 14, the same, and same movement of head, expansion of pupils, pricking of opposite ear; 15, lifting of lips and corner of nostril on stimulated side.

Ferrier, in 1873, and later in 1876 reported the discovery of numerous centres of electrical irritation on the cerebral hemispheres of the monkey. These were found, as reference to Fig. 893 will show, to lie close together about the Rolandic fissure in the central convolutions. Even after it had become generally accepted that the effect of these weak currents was not due to the conduction of the electrical stimulus to lower motor areas, but was the effect of the direct stimulation of gray matter in the cortex, which was thus proved to exercise a determining influence over the pathways of motor conduction, it still remained a matter of doubt as to the degree to which the specialized functions of muscle groups may be localized in the cerebral cortex. Some experimenters claim that minute areas, at first excitable, after a time cease to be so. Others report that a displacement of the excitable points may take place. Exner distinguishes between absolute and relative motor fields, the former being those wherein lesions are always followed by impaired motion, the latter being such as sometimes give rise to impaired motion and sometimes not. Panneth found that a number of minute areas or spots could be detected as lying in a larger excitable zone.

Although the investigations of Fritsch and Hitzig demonstrated the connection of the Rolandic convolutions with voluntary movements, the interpretation of their functioning remained uncertain for some time. Even at the present day, it is possible to find charts of the distribution of functions over the cerebral hemispheres, based upon the erroneous interpretation of Hitzig's results. Ferrier was above all others responsible for drawing a sharp line of demarcation between the purely motor centres and the sensory centres. According to this view the Rolandic convolutions are centres for the emission of motor stimuli only, their excitation perhaps giving rise to no consciousness whatever. The so-called motor areas are supposed to receive directly no afferent sensory stimuli, but to be physiologically stimulated from other portions of the cortex. Ferrier accordingly located tactile sensibility in the limbic lobe, particularly in the hippocampal convolution. He denied that such sensibility was interfered with by ablation of parts of the motor convolutions. A better understanding is chiefly due to Munk, though in second degree to the labors of Goltz and to the criticisms of Bastian.

Munk made a much more extensive series of extirpations of areas in the brains of dogs and monkeys than previous investigators had done. These led him to the conclusion that the occipital lobes are connected with the sense of sight, the temporal lobes with that of hearing. On removal of the area A_1 (Fig. 894) in a dog's brain on both sides, and examining the animal some days after the operation, he observed a peculiar disturbance of the sense of sight, without injury to any other sensory or motor function. The dog moves with perfect freedom without striking any obstacle, and when such are put around him, he eludes them by crawling under or jumping over them. But the sight of dogs or men, whom he had before greeted joyfully, now leaves him perfectly cold. However hunger and thirst may cause him to move about, he no longer seeks the accustomed place for his food, and will even pass it by as long as he does not smell it. A light held to his eye no longer causes him to blink, nor does the sight of the whip, which formerly drove him into the corner, produce any effect upon him. He had been trained to give his paw when a hand was held out, now he will not give it unless ordered to. "By the extirpation, the dog has become psychically blind, *i.e.*, he has lost the sight-presentations which he possessed, his memory pictures of former sight perceptions, so that he neither knows nor recognizes anything he sees." But the dog does see, and gradually forms a new store of sight memories. Munk further states that no matter how long the dog is kept alive, he never regains any of his former sight-memories, except by renewal of the experience. Complete removal of both sight areas, he asserts, causes total and permanent "cortical blindness"; if only one side be destroyed, hemiopia results.

In the same manner extirpation of a limited area in each temporal lobe produced what Munk calls "psychic deafness," a condition much like the so-called "word-deafness" in the human subject. The dog hears perfectly, but no longer understands words to which he had before been trained. Gradually, however, the dog learns how to hear. In the so-called motor zone the results are no less striking. In opposition to his predecessors, Munk maintains that the motor disturbances are always accompanied by sensory disturbances, which consist in the loss of the most complex feelings, the sense of position, of pressure, muscular sense, etc. He concludes that the paralysis is the result of the loss of motor

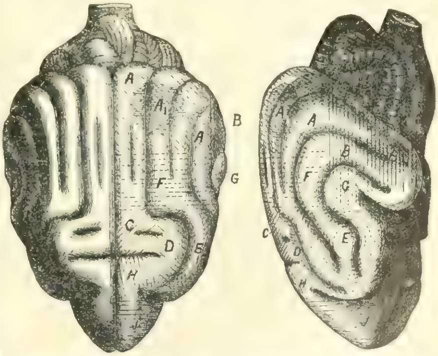

FIG. 894. Cortical Areas in the Dog. (After Munk.) AA, sight area; B, hearing; C, feeling of hind limb; D, of fore limb; E, of the head; F, of protecting apparatus of eye; G, of the ear; H, of the neck; J, of the trunk.

memories, and calls the motor zone the "area of feeling." Within this area (Fig. 894) are seven subareas, those for the fore and hind limbs, head, eyes, ears, neck, and body. The rapidity of restitution of function, when one of these areas is removed, depends upon the extent of the lesion; if it is all removed the defect is a permanent one. In the monkey's brain Munk obtained essentially the same results.

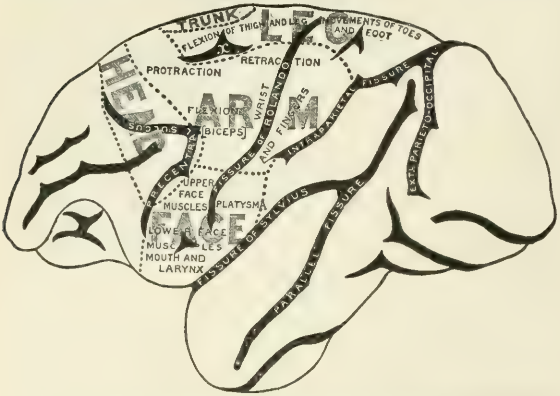

FIG. 895.—The Distribution of Motor Areas Over the External Surface of the Cerebral Hemispheres of the Monkey's Brain. (After Horsley and Schäfer, from Barker.)

A summary of the results of Beevor, Horsley, and Schäfer (1887–1894) will serve best to indicate the present status of knowledge as to the exact representation of different movements over the Rolandic convolutions of the monkey and orangoutang, which stand nearest to man in biological relationship. The anterior central gyrus, they find, is much more concerned in the motor function than is the posterior central gyrus. They conclude that within the area of motor representation for the limbs, the regions for the larger joints are generally at the upper part of the area, while those of the smaller joints and more differentiated movements are at the lower part. Movements of extension are represented in the upper part, while those of flexion are in the lower. There appeared to be no absolute line separating the area of one movement from that of another, each movement having a centre of maximal functional representation gradually shading off into the surrounding cortex. They distinguished a primary result of electrical stimulation from the subsequent epileptoid march of the movements as the electrical stimulus became diffused through the cortex. Their general scheme of motor representation is diagrammatically summarized in Figs. 895 and 896. The results from ablations of areas of the cortex were quite in accord with their findings by the physiological method. Suggestive is the report that muscular movements of each individual segment are much more fully represented in the cortex of the ourang than in that of the monkey. It seems a general law that the higher the animal the more definite is the area of representation not only of individual segments, but of individual movements belonging to one segment. This would suggest a still more specific motor representation in the human brain.

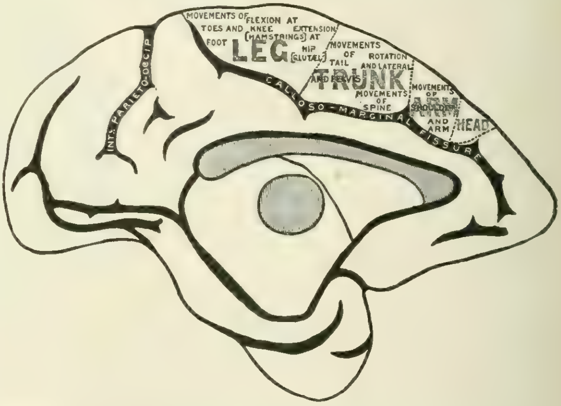
MOVEMENTS OF TOES AND FOOT
FLEXION AT KNEE (HAMSTRINGS)
EXTENSION AT HIP (GLUTEI)
LEG
MOVEMENTS OF TAIL AND PELVIS
ROTATION AND LATERAL
TRUNK
MOVEMENTS OF SPINE
MOVEMENTS OF SHOULDER AND ARM
ARM
HEAD
CALLOSO-MARGINAL FISSURE
INT'L PARIETO-OCCIP.

FIG. 896.—The Distribution of Motor Areas Over the Median Surface of the Cerebral Hemispheres of the Monkey's Brain. (After Horsley and Schäfer, from Barker.)

The subdivisions of the motor area in man have been ascertained from a large number of carefully reported cases and autopsies, and from the electrical excitation of circumscribed areas of the cortex during its exposure for cerebral operations. The exactness with which such localizations can be determined is remarkable. In 1888 Keen extirpated the focal representation of the wrist in the right cerebral hemisphere which he had fixed in relation to the areas for the movements of the elbows, shoulder, and face. After operation the left hand was found to be paralyzed as regards all movements of the fingers and wrist. The elbow was weak, but the shoulder and face were entirely unaffected.

The distribution of specific motor areas over the cortex of the human cerebrum is presented in Figs. 897 and 898. The following summary is based upon those of Mills and Gordinier, omitting details which in some cases are still doubtful. As shown in the diagrams, the specific leg area occupies the upper third of the two Rolandic convolutions, the arm area the middle third, and the face area the lower third. The trunk muscles are represented on the median surface of these two convolutions, the paracentral lobule. The leg area extends over the posterior part of the paracentral lobule and the upper anterior part of the superior parietal lobule; it occupies a greater antero-posterior surface than does the area of the arm or face. The movements of the thigh, knee, leg, foot, and toes are ranged in order from the front backward. The arm area is subdivided from above downward into centres for the movement of the shoulder, elbow, hand, and fingers. The movements of the shoulder are also represented in the anterior part of the paracentral lobule. The subdivisions of the face area contain from above downward the movements of the orbicularis palpebrarum and occipito-frontalis, the mouth, lips, tongue, pharynx, and larynx. The platysmal movements, according to Mills, are probably represented in the posterior part, and the larynx and pharynx in the anterior part. Movements of the head and eyes are probably represented in the posterior part of the first and second convolutions adjacent to the ascending frontal and on the median surface of the first frontal convolution. Those movements of the body which are always bilaterally innervated appear to have bilateral representation, so that an injury of one hemisphere, *e.g.*, of the laryngeal centre, fails to produce paralysis. Those movements, on the other hand, which may take place on one side of the body only, are represented in the assigned area of the opposite hemisphere only.

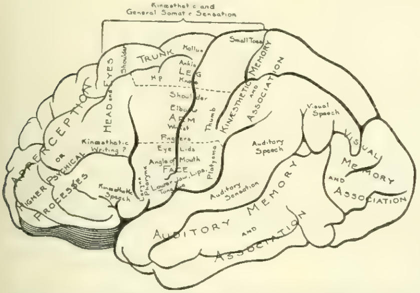

FIG. 897.—The Distribution of Sensory and Association Areas Over the External Surface of the Cerebral Hemispheres. The diagram shows: 1, The area of kinæsthetic and general somatic sensation, occupying the central convolutions and portions of adjacent convolutions. (This is usually called the motor area. It is both an emissive or motor and a receptive or sensory area. The localization of the subdivided sensorimotor areas is indicated in the diagram.) 2, the area of auditory sensation, occupying the middle portion of the superior convolution and adjacent portions of the transverse convolutions of the temporal lobe; 3, the area of association of the first order, occupying the occipital lobe, the second and third temporal convolutions, a portion of the superior temporal convolution, the insula, and the posterior parietal convolutions; 4, the area of association of the second order, or the zone of language, occupying the angular gyrus, the upper portion of the superior temporal convolution, the posterior third of the inferior frontal convolution (restricted to a single hemisphere, most frequently the left); 5, the area of association of the third order, the area of apperception, occupying the prefrontal regions of the frontal lobes.

To Munk, in the opinion of the writer, belongs the credit of offering a satisfactory interpretation of the relation between the motor and sensory functions of the cortex and between psychical disturbance and the loss of simple sensation. From this point on, I shall merely summarize the views of different authorities with respect to various cortical functions, considering first in order the sensory areas, and next the areas of higher psychical activity. The excitable motor area is a "feeling sphere," according to Munk, because it receives afferent stimulations which excite the cortical cells to give rise to sensations and ideas of bodily movement. Cortical stimulation, otherwise than through the afferent tracts, may awaken memories or ideas of such movements. Fritsch and Hitzig had indeed referred to the Rolandic convolutions as the area of the muscular sense. For a long time, however, sensations of the muscle sense were understood to be due to the efferent stimulus of the cells in that region. This notion gave rise to the theory of an "innervation feeling" or "sense," a theory which Wundt did not entirely give up until the appearance of the third edition of the "Physiologische Psychologie" in 1887. It is now accepted that the activity of purely motor cells of efferent conduction in the Rolandic region (probably the large pyramidal cells) is unaccompanied by consciousness; that sensations or feelings of bodily movement are primarily due to the activity of sensory cells of the same region which receive stimulation from the sensory conduction paths comprising the median fillet and posterior columns of the cord. Bastian made the valuable proposition to call these areas "kinæsthetic" areas or areas of "kinæsthetic sensation." Goltz's results were in many ways contradictory of both Munk's and Ferrier's, but this contradiction is to a great extent limited to details, and in the main his work is confirmatory of the trend of the results as indicated in this paper. Although he contended that it is not possible permanently to paralyze any muscle, he distinguishes between fine and coarse adaptations, and shows that although a dog's paw is not paralyzed as an organ of locomotion by the destruction of the cortex, it yet remains permanently paralyzed for all those actions in which it is employed as a hand.

The testimony of experimental physiologists, including in addition to those mentioned above Luciani, Horsley, and Mott, points unequivocally to the so-called motor area and immediately adjacent convolutions as the centre of kinæsthetic sensation and of touch, pressure, heat, cold, and pain sensation as well. For this reason the convolutions of motor function are designated in Figs. 897 and 898 as areas of kinæsthetic and general somatic sensation. Confirmatory are also the pathological findings of Gowers, Westphal, Seguin, Dana, and Starr. Dana's twenty-five cases, four of his own with twenty-one others, all prove that lesions of the central convolution are attended by partial or complete loss of tactile, temperature, pain, and muscular senses in the limbs of the opposite side of the body. Starr, after thirty cases of cerebral operations consisting of excisions of parts of the motor area, thinks that it is clearly determined that the tactile centres are situated in the Rolandic area, especially in the postcentral gyrus. Redlich, from an analysis of twenty cases of lesions confined to the parietal lobe, states positively that these lobes are the centres for muscle sense. Nothnagel, Luciani, Seppelli, and Flechsig long ago asserted that the parietal lobes were concerned in the reception of muscle sense impressions and possibly of the other forms of general sensation. Many pathologists whose opinions justly carry great weight are opponents of the view here represented. Among these, Mills is most worthy of mention as still contending for the restrictedly motorial function of the excitable areas of the Rolandic convolution and for a distinct representation of cutaneous and muscular sensations in the adjacent postero-parietal convolutions, precuneus and gyrus fornicatus. In support of this view

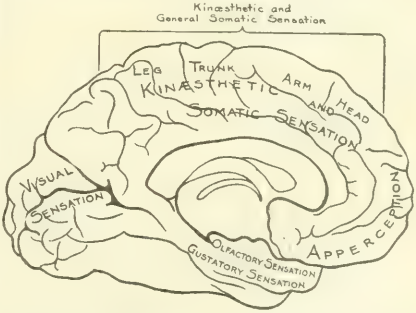

FIG. 898.—The Distribution of Sensory and Association Areas Over the Median Surface of the Cerebral Hemispheres. The diagram presents: 1, The area of kinæsthetic and general somatic sensation, occupying portions of the parietal and frontal lobes; 2, the areas of visual sensation in the convolutions adjacent to the calcarine fissure; 3, the areas of olfactory and gustatory sensation in the uncinate gyrus and adjacent cortex; 4, the area of association of the third order, or area of apperception, in the prefrontal convolutions of the frontal lobes. The portions of the parietal and temporal lobes to which no special function is assigned in the diagram are association areas of the first order.

he maintains that innumerable cases have been reported of lesions of the motor cortex without impairment of sensibility. He also cites his own experience with that of others which shows that surgical excision of the Rolandic cortex is not necessarily followed by any sensory impairment.

The results of histological investigation of the structural elements of the cortex in the main confirm the view that the functions of the Rolandic cortex are only in part motor. At least four layers of the cortex are distinguished—a superficial layer rich in small cells and tangential fibres, a layer of small and a layer of large pyramidal cells, and a deeper layer of polygonal cells which are supposed to give rise to short and long associational neuraxones. Only the pyramidal cells, perhaps only the very large pyramidal cells, are supposed to give rise to the projection neuraxones of efferent or cortico-fugal conduction—*i.e.*, those fibres which pass in groups functionally related through the internal capsule to the crura cerebri, to terminate about the motor cells of the cranial nerves of the same, but chiefly of the opposite side, or to continue on through the pyramids and, a portion crossed and a portion uncrossed, to terminate about the motor cells in the anterior horn of the cord, partly on the same and partly on the opposite side. The path of these projection neurones has been made out by the stimulation methods of Beevor and Horsley, Burdon Sanderson, Franck, and Pitres, and by the studies of resultant degeneration, first initiated by Türck in 1851, and subsequently extended by Bouchard, Charcot, Pierret, Nothnagel, von Monakow, Marchi, Hoche. The excision of limited areas of the motor cortex gives rise to secondary degenerations also; these have been studied by von Gudden, von Monakow, Franck, Pitres, Moueli, Marchi, Algeri, Muratoff, Mellus and Langley, and Sherrington. The true motor cells are so situated that they may be stimulated to activity by the constituent cells of the proximate cortex, by associational and commissural neuraxones from remote parts of the cortex, or by the neuraxones of afferent conduction which terminate, perhaps, in all four layers of the cortex. Cajal has presented a scheme of intercortical relation, and has constructed an elaborate theory of the neuronal mechanism of association, ideation, and attention. Problematic as this scheme remains, it indicates a new line of speculation as to cerebral functions, based on a discrimination of the various sensory, motor, and associational cells of a given part of the cortex, and promises much for a future better understanding of the specific psycho-physiological activities of the nervous system.

Edinger from embryological researches, and von Monakow from the study of secondary degeneration, report that the sensory fibres of the fillet or lemniscus terminate in the cortex of the postcentral convolution and parietal lobe. The afferent neuraxone terminations in the Rolandic convolutions are in functional connection with the nuclei of the mid- and hind-brain, particularly with those pathways of conduction which mediate common sensation. This area, therefore, is physiologically a sensory or receptive centre for cortico-petal stimuli of all sense tracts except the four sense tracts of special sensation, as well as the motor or emissive centre of the most important tracts of motor innervation.

The most extensive experiments dealing with the sensory fibres leading to this part of the cortex are those of Flechsig. He divides these cortico-petal fibres—which pass together through the internal capsule and which are the indirect continuations of the dorsal roots of the cerebral and spinal nerves—into three groups or systems, distinguished by the fact that they put on their myelin sheath at different periods. The first group becomes medullated at the beginning of the ninth fœtal month. It occupies the posterior part of the internal capsule and, in its upper half, the area immediately behind the fibres of the pyramidal tract. These fibres are distributed exclusively to the cortex of the two central gyri, which are thus the first regions of the cortex to become connected by means of medullated fibres with the sensory apparatus of the body (see Figs. 900 and 901). The second group receives its myelin about a month later than the first group. These fibres are distributed to the central gyri, the lobulus paracentralis, and the foot of the superior frontal gyrus. Another portion is distributed to the gyrus fornicatus along its whole length. The posterior bundles run toward Ammon's horn, and still another bundle enters into the uncus and arrives at the subiculum cornu Ammonis. The whole of the limbic lobe is thus connected with the lateral nucleus of the thalamus. The third system is also joined with the lateral nucleus of the thalamus and one part runs directly to the foot of the third convolution, another portion through the pars frontalis of the internal capsule into the frontal lobe almost as far as the pole, part of the fibres reaching the middle portion of the gyrus fornicatus, another part the anterior half of the superior frontal gyri, while single fibres go to the middle of the frontal gyri. Edinger and von Monakow also distinguish from the cortico-fugal pyramidal tract a fronto-cerebro-cortico-pontal tract. These fibres, according to Flechsig, arise in those regions of the cerebral cortex which correspond to the distribution of the third group of sensory fibres, *i.e.*, the feet of the three frontal gyri and possibly also the middle portion of the gyrus fornicatus. They terminate in the nuclei of the pons and are concerned with the movements of bilaterally innervated muscles, such as those of the eyes, neck, and trunk. The motor impulses concerned in the speech movements may also, he believes, be carried by these fibres, though according to Barker there is a good deal of evidence that the speech path is separate and distinct.

Results indicating the cortical localization of the area of vision have from the first been consistent in prescribing its limits to the occipital lobes and adjacent parieto-temporal convolutions. The location within these limits has been differently assigned; thus Hitzig to gyri in the posterior lobes of the dog, while Ferrier has persistently contended for the angular gyrus. Munk's careful and critical investigations prepared the way for an understanding of the relation of the different parts of the visual area. He distinguished between psychical blindness and the simple loss of vision proper, and found different areas giving rise to these diverse conditions. He interpreted the area of simple or primary vision to be the cortical projection field of the retina, whereas adjacent areas added those memory images which made visual impressions intelligible. Despite conflicting evidence, it is fairly well established that the primary visual areas of the cerebral hemispheres are situated in the neighborhood of the cuneus, and that the calcarine fissure bears about the same relation to visual stimulation as the Rolandic fissure does to somæsthetic stimuli. This statement refers, however, only to retinal stimulations, which constitute in reality only a very small part of those sensory stimuli which are essential for the maintenance of complete vision. Henschen proposes for this area the name of calcarine retina, and suggests, from an examination of clinico-pathological evidence, that the upper lip of the calcarine fissure of one hemisphere is the projection field of the lower quadrants of the visual fields of the homonymous halves of both retinæ, and that the lower lip has a corresponding connection with the upper visual fields. Henschen also assigned the cortical representation of the central portion of the retina to the anterior part of the calcarine fissure and of the peripheral portions of the retina to the posterior part. The macula seems from many results to have a separate and distinct representation and to be represented for each eye in both cortices, whereas the symmetrical halves of each retina are represented in the hemisphere of the same side only.

Cajal has shown that the fibres of the macula retained their individuality as far as the basal ganglia. It is denied, however, by von Monakow and others, that there is a distinct cortical area for the macula. He believes that it is represented in perhaps all portions of the occipital lobe constituting the visual area, even in the posterior part of the angular gyrus Examination of the results of pathological findings indicates the possibility of much individual variation both at the centres and along the conduction pathways. There can be little doubt that the cuneus (see Fig. 898, page 305) is the cortical centre of primary visual sensation, and that regions which ontogenically acquire the associational capacity of complex visual perception involving the visual memories of past experience, spread out over the convex surface of the occipital lobes and perhaps to adjacent lobes, certainly to the angular gyrus (see Fig. 897). Kinæsthetic stimuli from the muscles of the eyes are important elements in visual perception; whether these are conducted to the visual area also does not appear; it is probable, however, that sensations of eye movements are associated in this area with the light sensations due to retinal stimulation. This conclusion seems the more necessary since, according to Rámon y Cajal, Engleman, von Monakow, von Gehuchten, Kölliker, and Held, the centrifugal fibres start in the axis-cylinder processes of the pyramidal cells of the cortex and arborize in the superficial gray matter of the anterior corpora quadrigemina. Processes from these ganglia terminate in the nervous feltwork of the retina and are in functional connection with the motor nuclei of the ocular and other nerves supplying the facial muscles. The connection of the cortex with these subcortical ganglia suggests that the oculomotor functions of the occipital lobe are exercised centrifugally via the optic radiation, as maintained by Munk and Sherrington (see Fig. 899). Thus through these centrifugal neurones the retina, the ocular reflexes, and facial instinctive movements may be under the influence of the occipital cortex. Of the basal nuclei, *i.e.*, thalamus, external geniculate body, anterior corpora quadrigemina, connected with the visual function, the external geniculate body alone seems to be in direct relation to retinal stimuli. Lesion of this ganglion inevitably causes hemianopsia, and its destruction is followed by atrophy of the inferior portion of the bundle of Gratiolet. The pulvinar of the thalamus, on the other hand, may atrophy without producing hemianopsia if the geniculate body be intact. Lesion of the pulvinar and anterior corpora quadrigemina may, nevertheless, produce important modifications of vision. These ganglia appear to be centres of visual reflexes, such as winking, avoiding of obstacles, etc., the retinal reflex of contraction of the pupils to light, and perhaps even of acquired visual reflexes, such as the flight from a whip, etc. The expression of the emotions of involuntary origin appears to have its origin in the thalamus. The loss of the emotional involuntary reflex, at all events, may follow upon a lesion of this subcortical ganglion.

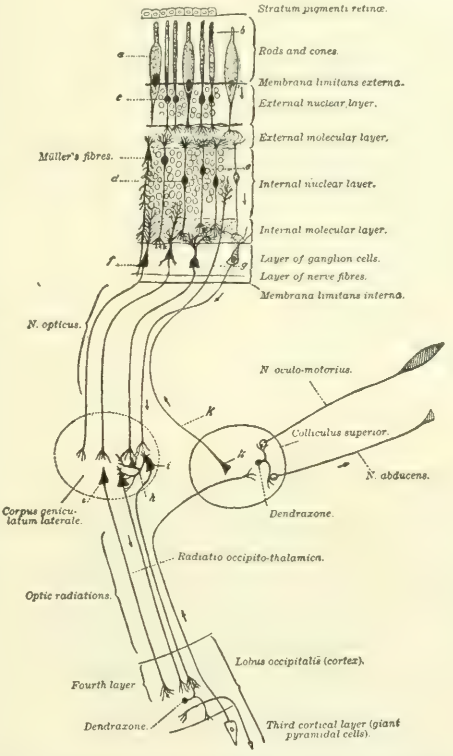

FIG. 899.—Diagram of the Visual Conduction Paths. (After von Monakow, from Barker.) *a*, *b*, *c*, Rods and cones of the retina; *d*, *e*, bipolar cells; *f*, large multipolar ganglion cells, giving rise to axones of the optic nerve; *g*, centrifugal axone of a neurone, the cell body of which is situated in the anterior corpora quarigemina (colliculus superior), its terminal dendritic processes being situated in the retina; *h*, Golgi cell of type *II*, in the lateral geniculate body; *i*, neurone connecting the lateral geniculate body with the occipital lobe, its axone running in the optic radiation of Gratiolet. The centripetal and centrifugal courses of the visual impulses are indicated by the arrows.

As in the case of cortical visual representation, the localization of the sense of audition has been restricted by almost all observers to a region of well-defined limits, in this case to the convolutions of the temporal lobe. Ferrier's results point to the superior temporo-sphenoidal convolution on each side, because electrical excitation of this area on either side invariably produced in the monkey retraction of the opposite ear associated with opening of the eyes and dilatation of the pupils; these movements Ferrier regarded as a significant index of auditory perception. Munk distinguished an area of greater intensity from adjacent regions of less intensity, both in the temporal lobes. Luciani considers the auditory sphere to extend over the whole cortical area of the temporal lobe. Pathological evidence has with equal decisiveness pointed to the temporal lobe. Bastian, Wernicke, Friedländer, Shaw, and Mills leave no room for doubt that the centres for hearing are situated in the superior temporal gyrus of each side. Each ear seems to be represented in both lobes, as both superior temporal gyri in man must be destroyed in order that total deafness shall ensue. The researches of Flechsig, von Monakow, Held, von Kölliker, Rámon y Cajal, and Florence Sabin have shown the anatomical relations of the cochlear branch of the auditory nerve, which alone is concerned in hearing, with the various basal nuclei, the chief of which are the trapezoid nucleus, the superior olive, the posterior corpora quadrigemina, the median geniculate nucleus, and the nucleus lemnisci lateralis. The fibre tracts connecting these various nuclei furnish an anatomical basis for more than one pathway of partial decussation. These fibres are also connected with the anterior corpora quadrigemina and with the motor nuclei of the cranial nerves, thus constituting a basal organ for automatic movements of the head, and perhaps of the trunk, in response to auditory stimulation. It is not deemed advisable to present the several parts of the complicated pathway of afferent conduction, as these have been made out by various investigators. It will suffice to mention that the collected fibres from these various nuclei pass as the lateral fillet, according to Flechsig in two separate bundles, to the internal capsule, and go transversely through the same in two separate bundles to the transverse gyri of the temporal lobe. The one bundle ascends near the external capsule and arrives from behind and above into the auditory sense area. The other runs for some distance along with the occipito-thalamic radiations, and passes around the fossa Sylvii from behind and below into the temporal lobe itself, close by the second and third temporal gyri, to reach the transverse temporal gyrus. The exact extent of the sense region, according to Flechsig, corresponds to the two transverse gyri of the temporal lobe, particularly the anterior and that portion of the superior temporal immediately adjacent (see Figs. 900 and 901, on pages 308 and 309).

The giant pyramidal cells, which are believed to give origin to the cortico-fugal projection tracts, seem to be absent in this region. Flechsig nevertheless maintains that the temporo-cortico-cerebro-pontal path begins here. The axones of this bundle of fibres, usually but mistakenly called Türck's bundle, pass down, through the anterior portion of the occipital part of the internal capsule, to the lateral region of the base of the cerebral peduncles; thence they go into the pons, terminating perhaps in the nuclei of that region. Flechsig is inclined to think that this temporal path represents a mode of connection, by way of the brachium pontis, of one cerebral with the opposite cerebellar hemisphere. The fibres are medullated at a later period than the fibres of the pyramidal tract; Von Monakow and Déjerine also report on this tract Déjerine believes, however, that the bundle arises from the whole temporal lobe, but chiefly the median and inferior convolutions. Whatever the origin, course, and termination of this tract may be, there can be little doubt as to its existence. The evidence seems to point to the middle part of the superior temporal convolution as the primary cortical auditory area (see Fig. 897, page 305), while the areas for more complex auditory perceptions are located in the upper part of the second and third convolutions toward the angular gyrus, and perhaps extend downward over the fourth and fifth temporal convolutions also, a region in which Mills places a centre for the hearing of words—the so-called "naming" or "idea" centre.

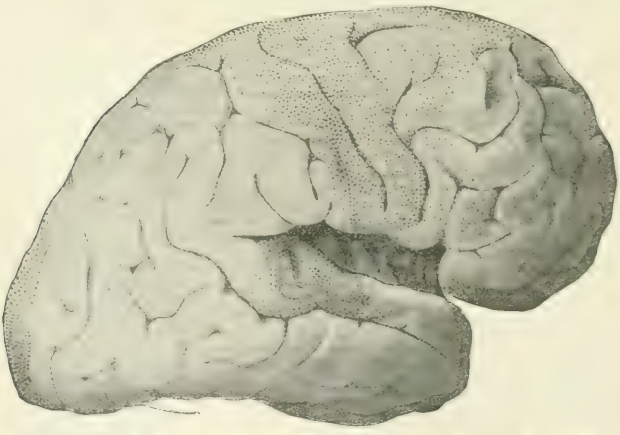

FIG. 900.—The Sense Areas and Association Areas on the External Surface of the Right Cerebral Hemisphere. (From Flechsig.) The closely dotted areas about the central fissure, on the middle part of the superior temporal convolution, and in the posterior part of the occipital lobe, indicate respectively the primary areas of general somatic sensation, of auditory and of visual sensation. The regions not marked with the dots are: 1, The posterior association areas in the parietal, occipital, and temporal lobes; 2, the middle association area in the insula; 3, the anterior association area in the frontal lobe. As the thickly dotted regions shade off into the unmarked regions, so the primary sense areas are continued into adjacent portions of the association areas, presenting a gradual transition from the simpler to the more complex functions.

The vestibular branch of the auditory nerve is connected with nuclei which are in anatomical relation with the cerebellum and with the median fillet; thus stimuli from this branch may pass to the somæsthetic area of the cerebral hemispheres.

Ferrier located the sense of taste and smell in the subiculum and in neighboring portions of the lower temporal convolution. Munk localized smell in the gyrus hippocampus. According to Andriezen, the cortical regions which receive the olfactory projection fibres are (1) the region of the genu of the gyrus fornicatus; (2) the septum lucidum; (3) the inferior extremities of the hippocampal and uncinate gyri. Hill looks upon the fornix as one of the conduction paths, and this is certainly in accord with the relation of that structure to the terminal cortical areas just named. Cases have been reported by Ogle, Jackson, Hamilton, Worcester, and others, in which impairment or loss of smell was associated with lesions of the gyrus uncinatus or its immediate vicinity. According to Flechsig, the olfactory conduction path in the forebrain is the first path connected with the special sense organs to become medullated. Turner grouped the regions especially connected with the sense of smell in 1865 under the term rhinencephalon. His and Edinger consider this separation of the parts concerned with smell to be in accord with the facts of embryological and phylogenetical development. The rhinencephalon is rich in neurones connecting it with the basal ganglia; these lower centres are therefore so situated as to be able to respond reflexly or anatomically to all forms of general or special sensory stimulation. The gyrus hippocampus, especially the uncus, appears to be established as the cortical sensory area for olfactory stimulation. The cortical area for the sense of taste is probably located adjacent to the area for that of smell, perhaps occupying in part a portion of the fourth temporal convolution. Turner (1897) in reviewing the subject finds disagreement among investigators as to the peripheral gustatory neurones and almost complete ignorance as to the central neurones. Bechterew has presented a scheme of taste conduction paths. Peripherally these involve the fifth and ninth nerves in the region of the fourth ventricle, where they are associated with the motor nuclei of the fifth, seventh, and ninth nerves. The limited knowledge pointing to a definite location of taste sensation is in accord with the relative unimportance of this sensation and with its close association to the sensations of smell, of touch, and of temperature.

The primary centres of sensation occupy only about one-third of the superficial surface of the cerebral hemispheres (see Figs. 897, 898, 900, and 901). These physiologically are higher sensorimotor centres superimposed upon the lower basal centres, and enable the organism which possesses them to act in response to stimuli with more complicated coordination than would be possible with the basal and other lower centres alone. In Figs. 900 and 901 the central portion of each sensory area is indicated by the more numerous dots which represent, according to Flechsig, their richer supply of cortico-petal fibres, while the less frequent dots represent the portion in which these fibres are less numerous. The remaining two-thirds of the cerebral area, unmarked with dots, are not provided with projection fibres either afferent or efferent. The white matter of all these cortical regions, with the exception perhaps of that beneath the angular gyrus, becomes medullated considerably later than that of the sense centres, so that even in children three months old the former are sharply distinguishable from the latter by their poverty of myelin. Flechsig finds, however, that medullated paths gradually grow out from the sense centres into these non-medullated regions. Further, between the individual gyri of the non-medullated regions, bands of association fibres gradually ripen, connecting the individual gyri with others near them and also with gyri at a distance. These areas Flechsig designates association areas; through these alone one sensory area is indirectly connected with another. The association areas are therefore centres whose cells are superimposed upon those of lower primary sensory areas, supplying a mechanism for the higher co-ordinations which are most representative of the intelligent as well as of the conscious life of the organism. He designates as the posterior association area that part which includes the precuneus, all the parietal gyrus, except the postcentral gyrus, part of the gyrus lingualis, the fusiform gyrus, and the middle and inferior temporal gyrus, as well as all portions of the occipital gyrus not concerned in the visual sense area. This association region is therefore situated midway between the visual, the somæsthetic, and the auditory sense areas, and is indeed not remote from the olfactory and gustatory areas. The middle association area is constituted by the island of Reil, surrounded by the somæsthetic area, the auditory area, and the olfactory area, from all of which bands of fibres run into it. The prefrontal convolutions constitute the anterior association area, which is chiefly connected with the somæsthetic area and the olfactory sense area.

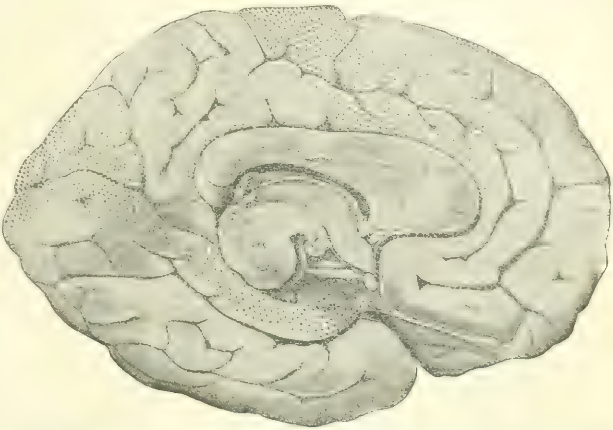

FIG. 901.—The Sense Areas and Association Areas on the Median Surface of the Left Cerebral Hemisphere. (From Flechsig. The closely dotted regions in the anterior portion of the parietal and posterior portion of the frontal lobes, about the calcarine fissure, and in the hippocampal and uncinate gyri, indicate respectively the primary sense areas of general somatic sensation, of visual sensation, and of gustatory and olfactory sensation. The regions not marked with dots are: 1, The posterior association area in the precuneus and temporal lobe; 2, the anterior association area in the frontal lobe.

The facts advanced by Flechsig are admitted in part, but contested in part also. Thus von Monakow asserts that projection fibres go to nearly all parts of the cortex, though he, as well as all others, admits that some parts receive fewer by far than others, the frontal lobe especially receiving few, if any. Some also deny that association tracts connect the sensory areas only indirectly through the association areas. These tracts have been made out in some instances with much precision. The polymorphous cells of the fourth layer and of the pyramidal layers are admitted to give origin to the fibres that either separately or as constituents of well-defined tracts unite in functional relationship the cortices of separated convolutions.

By means of the corpus callosum the gyri in one hemisphere are connected with those in the opposite hemisphere. Of short association fibres there are five different bundles that have been made out in the occipital lobes alone. In the frontal lobes, fewer distinct bundles of association fibres have been made out, although Déjerine has described the source of several. In the temporal lobe and insula, similar bundles have been described but no definite tracts have been ascertained. The long association tracts that have been described are, according to Barker: (1) the cingulum, which belongs to the rhinencephalon; (2) fasciculus longitudinalis superioris, connecting the frontal and occipital lobes; (3) fasciculus longitudinalis inferioris, uniting the occipital and temporal lobes; it is suggested that this may be the bundle connecting the visual sense area with the auditory sense area; (4) fasciculus uncinatus, which extends between the uncus and the basal portion of the frontal lobe, and which may be an association tract of the rhinencephalon; (5) the tapetum, which is held by some to be a portion of the fasciculus longitudinalis superioris. According to Déjerine, it arises in the whole cortex of the frontal lobe, and, passing through the tapetum, its fibres are distributed to the lateral surface and inferior border of the lobus occipitalis.

These results seem to establish a direct connection between the various sense centres, as well as the indirect connection through the association areas as proposed by Flechsig. Whether Flechsig be right or wrong in this, whether subsequent research shall substantiate or disprove the anatomical connections and relationships indicated by the report of his results of the embryological method, it seems to the writer that Flechsig's psychophysiological interpretation of the functions of the association areas is in the main incontestibly sound in psychology, and accordant with the trend of conclusions drawn from multifarious experimental and clinical investigations.

It has already been pointed out that most authorities distinguish between sensory disturbances and perceptual disturbances. Loss of memory and of higher sense perception have generally been attributed to regions which lie from the direction of the auditory, visual and somæsthetic areas toward the angular gyrus. It is immaterial whether psychical blindness, deafness, etc., are due to a loss of memory images or to an ataxia of sense perception. It seems clear that the nearer a lesion lies to the calcarine fissure, the Rolandic fissure, or the middle part of the temporal convolution, the more likely is the injury to give rise to a loss of sensation only; and the nearer the injury is to the angular gyrus, the more likely is the result to be a loss of perception, ideas, and memories connected with sensory impression. And yet it is difficult, both on the physiological and on the psychological side, to distinguish a pure sensation from one with an admixture of memory images. What a sensation would be utterly divorced from integral connection with the consciousness of the individual it is impossible to say. The association centres of Flechsig are centres of perceptual and ideational integration. Through their activity, in conjunction with the functions of the sensory areas, the actions of the human being are able to reflect the influence of acquired individual experience.

The posterior association centre (see Fig. 897, page 305, and Fig. 900, page 308) is concerned chiefly with the intellectual processes. Injury to the cells of this centre is followed by various forms of psychical blindness, by apraxia, agnosia, amnesia, and sometimes a weakening of the imagination. The anterior association centre is most closely associated in function with the somæsthetic area, and hence also with the motor regions concerned in conduct, so that here in all probability is to be sought the anatomical mechanism by means of which the memory effects of all conscious bodily experiences, especially of acts of will, are retained. In injuries to this region, Flechsig maintains, interest in the external world is lost and the most marked alterations of character, attention, reflection, and inhibition are manifest. There may be symptoms of over-appreciation or of great self-depreciation; the speech may for a long time remain unaffected, but judgment as to what is right and wrong, beautiful and hateful, will be impaired, and there may be lack of self-command, even when uninfluenced by violent emotions, readiness to yield to sexual excitement, and finally imbecility. When the posterior association centres are mainly involved it is knowledge of the external world, rather than of his body and personality, that is impaired. Ideas regarding the objects of the external world are confused, there is a poverty of ideas or an inability to express them in words, yet with all this the patient may have perfect self-possession and a normal regard for himself and his friends.

These two association centres are not connected with each other excepting through the somæsthetic area. Flechsig, accordingly, seems to assume a more or less significant distinction between the intellectual processes and those of volition. The centres are bilateral and are richly connected by fibres of the corpus callosum. In this they are distinguished from the middle association centre, the island of Reil, which is very sparsely supplied with these commissural fibres. This centre seems to be for the one hemisphere only. It is the association centre more particularly for the cortical elements concerned in the speech function, situated, as it is, in such close proximity to the inferior frontal convolution and to the temporal convolution; it is therefore in connection with the portions of the posterior association centre that are connected with the visual and auditory speech functions. These functions are so closely connected with the intellectual processes that a few words on the most recent conclusions as to their nature and localization will assist toward a comprehension of the relation of the association centres to the rest of the nervous system.

The history of the study of the symptom complex known as aphasia throws an interesting sidelight on the localization of cerebral function. Mention has already been made of the conclusions of Wernicke, Kussmaul, and others. It is quite impossible to enter in this connection into an analysis of this very important chapter of cerebral localization. Collins' monograph on the "Genesis and Dissolution of the Faculty of Speech" gives a concise critical résumé of the various views, and sketches a theory of speech location essentially in harmony with that of Déjerine, and, in the opinion of the writer, most satisfactory from all points of view. By the time of Kussmaul the three elements involved in aphasic disturbance were well recognized—the motor emissive element, the visual element, and the auditory element. Charcot deserves the credit of emphasizing the fact that so-called motor aphasias are generally kinæsthetic aphasias, depending upon the loss of motor images. He believed that there was an articulate speech centre in the inferior frontal convolution, and a graphic kinæsthetic centre in the middle frontal convolution. An individual who depended in speaking or writing upon kinæsthetic images originated in these centres, Charcot called a moteur; one who depended on the visual elements was a visuel; and one who depended on the auditory elements was an auditif. The predisposition to belong to one of these three types might be inherited or might be acquired by education. The centres for the auditory and visual elements lay close together in the neighborhood of the angular gyrus. Charcot taught that these centres must act in harmonious co-operation in order that intellectual expression and conception should be complete. These centres were, however, independent, and an injury to one might remove certain elements without necessarily interfering with the others.

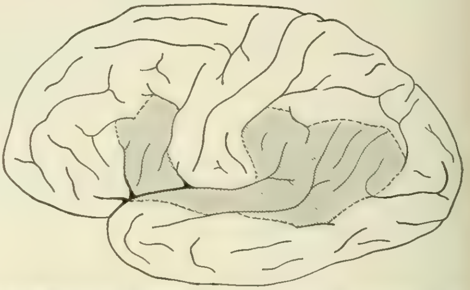

FIG. 902. The Zone of Language, According to Déjerine. (From Mills.) The zone of language, as indicated by the shaded regions, comprises the portion of the third frontal convolution posterior to the ascending branch of the fissure of Sylvius and the lower extremity of precentral convolution, the upper portions of the first and second temporal convolutions, and the supramarginal and angular convolutions of the parietal and occipital lobes.

This view was a great improvement upon the complex schemes that had been evolved by the Germans, of whom Lichtheim showed that no less than fourteen different areas might be the seat of a lesion producing aphasia. Naming centres, ideational centres, propositionizing centres, and the like were thus cast aside. A tendency toward an extreme of localization for different phases of the faculty of speech was in this way checked. Déjerine made a great step in the direction of still greater simplicity. He established the dependence of sensory agraphia upon loss of visual memories in the angular gyrus, which causes alteration of internal language, due to loss of visual images associated with word-blindness. He maintained that writing with the hand was not a specialized function but simply the outward expression through the hand of visual images of various graphic symbols. This view is not accepted by some authorities, notably Mills, Gordinier, and Bastian, who still maintain the existence of a graphic centre. It may appear that in certain individual cases the cells in the second frontal convolution may be so trained by education that after adult life is reached the destruction of these cells may cause an inability properly to co-ordinate the muscles of the arm. The graphic-motor centre appears nevertheless to be less stably established as a specifically differentiated portion of the cortex than is the kinæsthetic speech centre in the left inferior frontal convolution. Déjerine also contended against the functional independence of the three speech centres, mantaining that the language centre is really a zone constituted of portions of the temporal, parietal, and inferior frontal convolutions of which the three recognized speech centres were focal areas of most intense representation. The extent of this zone of language, which is shown in Fig. 902, is not strictly delimited. Collins says: "It varies in individual cases and at different periods of life in the same individual; namely, it is subject to phylogenetic and to ontogenetic variations as well, the latter depending somewhat upon the speech acquisition of the individual and on the range and number of avenues by which he receives or has schooled himself to receive information from language."

An injury to any portion of the zone of language will produce disorders of all the elements of speech function. This centre is emissive to the cortex of the Rolandic region, in which there are separate areas for the movements of respiration, vocalization, and lingual and labial action, from which proceed the true motor impulses. The centre in which are stored visual images is situated in the angular gyrus; the auditory centre occupies a position in the posterior part of the first temporal convolution immediately adjacent to the gyrus; the island of Reil may be involved. The speech zone receives and combines impulses coming into it from the auditory, visual, and kinæsthetic areas.

The views of Déjerine are in opposition to the theory of a cortical centre as a restricted area performing a certain specific psychical function and no other. Very similar are the views of Flechsig. The parts of the sensory areas which produce simple sensations have been shown to fade insensibly into the regions which perform functions related to more developed perception, and these shade off again into areas of ideation and conception, whose functioning constitutes a summation of impressions from all sense regions. For these areas I believe we may accept Flechsig's boundaries and name of posterior association centre. Perception, ideation, imagination, memory, thought, reason, etc., are not distinct psychical processes, but all are analyzable psychologically into associations or groups of ideas of more or less remote sensory origin. As these mental processes are revealed only through external expression, the cortical areas in which they are represented, of which the angular gyrus is the topographical centre, have a motor side also. In the same manner that the pyramidal tracts from the motor areas act ultimately upon the cells of the lower motor nuclei to induce more complex co-ordinations than are possible when spinal or basal centres act alone, so it is the function of the cells of the association area to act in a more complicated way upon the Rolandic neurones and other projection tracts. A part of this association area, Déjerine's zone of language, is shown to be connected with the association of those elements which constitute language, a function which has grown in the history of the race to have an amazing significance for man's intellectual life. Consequently I believe we may separate the zone of language (including the posterior third of the inferior frontal convolution, doubtfully the posterior third of the second frontal, the island of Reil perhaps, the angular gyrus, the upper part of the first and perhaps second temporal convolutions) from the rest of the association zone, as an area representing higher co-ordinations peculiarly significant for the processes of thought. We may designate the zone of language as a higher association area, or an association area of the second order. This specialized association area has a representation on only one side of the brain, whereas we have reason to believe that both cortical association areas take part in the simpler intellectual processes, although that on the left would appear to be somewhat more important. In special cases the right zone may perform language functions, even in right-handed persons, just as many persons learn to write with the left hand if the right has been injured or removed.

The prefrontal lobes have been variously designated as "silent" or "functionless" areas, as higher psychical centres, as centres of inhibition, as apperception centres, and as centres of the will and personality. So great is the misunderstanding of the nature of the functions of these lobes, even at the present time, and so often is positive evidence wrongly interpreted and even misquoted, that a somewhat extensive presentation of the facts and conclusions with respect to their functions is demanded.

The result of stimulation of these regions is negative, hence they are designated as silent areas. Ferrier, however, reports movements of the head and eyes, and early suggested that these might be movements characteristic of attention, which is the basis of intellection, and that these lobes might therefore be considered areas of higher psychical function. Extirpation of these prefrontal regions in dogs and monkeys by Hitzig, Ferrier, Horsley and Schäfer, and Goltz was accompànied by slight, hardly noticeable, mental deterioration. Munk and other observers, on the other hand, deny any loss of attention, perception, thought, or inhibitory power. Many authorities report areas for movements of the head and neck and of the trunk, and such centres are now assigned to the roots of the upper frontal convolution.

Bianchi (1888–95) contributed the first experimental demonstration conclusively pointing to the psychical functions of the frontal lobes. His experiments were made upon twelve monkeys and six dogs, all of which he subjected to very minute observations both before and after the operation, these observations extending in some cases over a period of years. To determine the boundaries of the prefrontal zone, Bianchi stimulated electrically all of the frontal region and excised all portions from 2 or 3 mm. in front of the excitable areas for the arm, face, jaw, and trunk. No special effort was made to preserve the olfactory bulb in the monkeys, but it was kept intact in the dogs. The results of electrical excitation agree with the conclusions of other observers.

Regions in front of the motor area of head, neck, and eyes were found to be unexcitable with a current of equal strength. Stimulation of the base of the upper frontal convolution produced slight rotation of the head to the opposite side and some lateral displacement of the trunk at the level of the lumbar region. Excitation of the inferior area caused raising of the eyelid together with dilatation of the pupil. The results which Bianchi obtained from unilateral extirpation may be summarized as follows:

1. During the first weeks were noted rotatory movements, concavity of the trunk toward the mutilated side, and paresis of the opposite arm (obvious in the more delicate movements). These symptoms disappeared at the end of two or three weeks. No oculo-motor disturbances were observed.

2. Tactile sensibility was normal except in one dog (diminished in opposite limb) and one monkey (hyperæsthesia in opposite ear and face).

3. In one monkey there was diminution of hearing on one side.

4. Taste and smell appeared normal.

5. In all cases there were visual disturbances. A piece of sugar was not seen with the right eye until it was nearly in a line with the visual axis. The left eye appeared to be normal.

6. There was no perceptible difference in behavior or psychical manifestations of animals mutilated on one side only. They were still susceptible of feelings and capable of new adaptations.

When both lobes were removed, there was apt to be a weakness of the left limbs and a tendency to rotate toward the right; but in some cases, after a time, all movements were perfectly performed, though in a listless, automatic fashion. Sensibility was not necessarily disturbed. There was a decided lack of interest, the habitual state seeming to be one of indifference, and the strongest feelings manifested were terror and the desire for food. Affection for the keeper and for the other animals disappeared. There was a lack of power to make new adaptations, to defend themselves, and to resist the influence of sensory stimuli. For example, the monkeys would pick up and eat a piece of plaster as readily as a piece of sugar. Even if they spit it out after breaking it up, as sometimes happened, they would return to the fragments and swallow them, apparently unable to resist the resemblance to sugar. Psychical life seemed to be reduced to the existence of actual sensations; there was no change or resource, and experience profited nothing. Perception seemed to lack some of the factors necessary to the formation of a complete judgment. There were crude sensations, but no co-ordination of simple presentations into representations of higher complexity.

Bianchi's conclusions are as follows: Paralysis of the trunk muscles does not always occur, and it is in any case but temporary. The phenomena observed upon destruction of the frontal lobes cannot be explained by the occurrence of a temporary trunk-muscle paralysis. Bianchi does not look upon Ferrier's hypothesis as satisfactory. The facts obtained point to more than a simple defect of attention correlated with paresis of ocular and cervical muscles.

Bianchi does not accept the view that the frontal lobes are distinctively inhibitory centres. On the contrary, he justly contends that every part of the nervous system becomes under different circumstances an inhibitory centre. When some particular area of the brain is excited there is an afflux of nervous waves into it, and this weakens the aptitude of other regions to fulfil their functions. If busy with a problem one becomes deaf and blind; if auditory or visual centres are strongly excited, the flow of ideas is weakened or arrested. Bianchi's final conclusion may be stated thus: In the frontal lobes, the incoming and outgoing products of sensory and motor areas are co-ordinated and fused with the emotional states that accompany perception; this area, therefore, determines what has been called the "psychical tone" of the individual.

From the time of Bouillaud many cases have been reported of injury to the frontal lobes without sensory or motor symptoms and with no apparent diminution of intellectual capacity. In the light of more recent knowledge of the effects of lesions in this region of the cerebral hemispheres, it is no doubt correct to infer that these cases were not carefully observed. For example, the American Crowbar Case, 1868, in reality a classical instance of conclusive evidence as to the peculiar functions of the prefrontal area, is still frequently misquoted and wrongly interpreted in medical literature, despite the critical analysis of Ferrier and Mills. The subject of this injury was a young man, twenty-five years of age. At the time of his injury, he was engaged in tamping a blasting charge in a rock with a pointed iron bar three feet seven inches in length, one and one-fourth inches in diameter, and weighing thirteen and one-fourth pounds. A premature explosion drove the bar clean through the frontal region of the skull, entering at the left angle of the jaw and passing out near the sagittal suture in the frontal region. The patient recovered and lived for twelve and a half years afterward. From a post-mortem examination of the skull it was clearly seen that the whole lesion was situated anterior to the coronal suture, and hence embraced only the prefrontal region. The following report, by Dr. Harlow, of the patient's mental condition after recovery from the injury presents a typical picture of mental decadence:

"His contractors, who regarded him as the most efficient and capable foreman in their employ previous to his injury, considered the change in his mind so marked that they could not give him his place again. The equilibrium or balance, so to speak, between his intellectual faculties and animal propensities seems to have been destroyed. He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operations, which are no sooner arranged than they are abandoned in turn for others appearing more feasible. A child in his intellectual capacity and manifestations, he had the animal passions of a strong man. Previous to his injury, though untrained in the schools, he possessed a well-balanced mind, and was looked upon by those who knew him as a shrewd, smart business man, very energetic and persistent in executing all his plans of operation. In this regard his mind was radically changed, so decidedly that his friends and acquaintances said he was 'no longer Gage.'"

Corroborative evidence is contained in many subsequent observations. Lepine, in 1877, reported a case of abscess of the right frontal lobe in which the patient "was in a state of hebetude." He seemed to comprehend what was said but could scarcely be got to utter a word. Barabuc, 1876, reported a case of atrophy of the frontal convolutions in both hemispheres in which muscular power and sensation were unimpaired, but the patient was in a state of complete dementia, marching about restlessly the whole day, picking up what came in his way, mute and quite oblivious of all the wants of nature and requiring to be tended like a child. Davidson, 1876, reported a case of injury to both frontal lobes in which the only symptoms were of a psychical nature. Every action that this patient performed left the impression on the mind of the observer that it was purely automatic or machine-like. Cruveilhier reports a case of complete idiocy from birth until the age of fifteen, with atrophy of two-thirds of the frontal lobe. Ferrier states that the frequent association of idiocy with such defect of the frontal lobes is a generally recognized fact.

Williamson, 1896, presented five cases of gross lesions, tumors, and abscesses involving the prefrontal region of one or both hemispheres in which were noticed marked mental symptoms. He gives the following instructive summary of these and forty-five other cases recorded in recent medical literature:

A condition of mental decadence; a dull mental state; loss of power of attention; loss of memory; loss of spontaneity; the patient taking no heed of his surroundings; sleeping during the greater portion of the day, or being semicomatose. (In two of these it is noted that the patients were in a perplexed mental condition, and constantly appeared to be searching for something.)	32
Loss of memory; mental failure, but patient cheerful	6
Patient suspicious; suffered from delusion, and was occasionally violent	1
Patient irritable and violent	1
Patient generally asleep; irritable when awake	2
Patient ambitious, excitable; memory lost	1
Slowness of mental processes; patient simple and childish.	1
Mental anxiety; childishness; hallucinations; suicidal tendencies	1
Mental condition not stated	5
	50

It may be considered as having been demonstrated beyond the possibility of a doubt that injury to one frontal lobe probably, and injury to both lobes certainly, will cause mental deterioration. The amount and character of this deterioration can be ascertained only from a careful detailed examination of the antecedent and subsequent capacities of the individual. In general, the phenomena are slight intellectual degradation, moral and emotional perversion, deficiency of attention, and volitional inefficiency. The functions of these lobes seem peculiarly representative of the mental character and general conduct as these have been developed as the result of a lifetime of education and action. These areas may therefore be designated association areas of the third or highest order. They exercise no functions which are not performed by the other association areas in less degree of complexity. Wundt calls these areas, centres of apperception; an appropriate term if we remember that apperception is a synthesis or organized coordination of all the acquired intellectual and other responsive reactions of a brain to the environment of the individual possessing it. As pointed out by Waller, it is thus a "high-level neural synthesis"; similar syntheses of lower level being accomplished by other portions of the cerebral hemisphere. Hughlings Jackson presented a similar view in the suggestion of a hierarchy of neural processes.

Stripping the individual, who has attained adult life, successively of his prefrontal lobes, the association zone of language, the other association areas, will successively reduce him to a lower grade of human being than he has come to be. The cells of the prefrontal lobes may be put to different uses in the brains of different persons. Loss of the frontal lobes might leave a Descartes still a fairly satisfactory college professor. The loss of these lobes and of portions of the other association areas might not unfit the college professor to live the normal life of a day laborer whose frontal lobes may be put to a strain to maintain his lower standard of activities.

It may be well to summarize the general conclusions of this article and to indicate the point of view from which these conclusions have been examined. It is customary to distinguish between sensory and motor functions of the nervous system, as though certain nerve elements performed the duty of supplying us with sensations, and others contributed an equal service by bringing about our movements. Waller has emphasized the objections to this view, maintaining that no centre is exclusively either motor or sensory, but that all centres are both sensory and motor. In this, he correctly interprets the facts, which show that brain centres physiologically perform their functions only when they both receive and emit stimuli. It would clear up many psychological notions, that are often confusedly interwoven with reports of the function of various centres, if it were kept constantly in mind that no centre, no neurone, and no nerve is motor, and on the other hand that no centre, no neurone, and no nerve is sensory.

All manifestations of life and consciousness are presented in the movements of the organism. These movements are, therefore, the immediate phenomena. A movement, even though it may possibly be restricted to a single muscle, is yet the summation of the contraction of its individual fibres. The function of any nerve fibre is not to produce a movement, but to stimulate or irritate a muscle fibre to exercise its inherent function of contracting. Similarly, it is the function of an afferent nerve fibre not to convey a sensory stimulus, but to innervate the neurone or neurones about which its central dendrites terminate. Even the simplest reflex action is the result of the co-ordination of at least two nerve elements which are intercalated between the peripheral point of application of a stimulus and the muscle fibres to which the motor neurones run. A single segment of the spinal cord, through the anatomical relationship of its neurones, is capable of serving as the reflex centre for complicated co-ordinated movements. The explanation as to why certain definite movements are elected to follow in response to a given stimulus is partly anatomical and partly physiological. In the first case, the answer ultimately reverts to biology to explain why neurones should be found so located as to be capable of mediating particular movements in response to definite stimuli. If we ascribe the cause to the functional habit of the neurones, we again must refer the question to biology to give an explanation of the inheritance of this congenital function, or to tell how neurones acquire during their existence in the organism a particular function or habit. When spinal centres comprise more than one segment, the problem remains the same: more neurones with their axis-cylinder processes have been intercalated, and the response of the peripheral neurones is now conjointly inspired by a larger group of neurones. The movements that result upon stimulation of more extensive centres will be characteristically different from those of segmental origination, but nevertheless these movements will still depend upon the interrelations of the neurons in the centres or upon an acquired or inherited habit.

The neurones, which are alone capable of stimulating muscle fibres, are located in the anterior horns of the cord and in the nuclei of the motor cranial nerves. These neurones may therefore be acted upon by peripheral neurones of afferent conduction alone, in which case they will respond with simple movements; or they may be acted upon by other additional central neurones. These constitute aggregated masses in the medulla oblongata, the cerebellum, the various basal ganglia, and the cortex of the cerebral hemispheres. As one mass after another is added, the peripheral motor neurones become the recipients of stimuli from larger and larger groups of central neurones, and the co-ordinated movements that follow will represent the combined or co-ordinated influence of their various cell elements. Thus, in the spinal cord, the neurones suffice to bring about simple reflexes; by adding the neurones of the cerebellum, more complex movements of locomotion are produced; adding the basal ganglia contributes the anatomical elements that render the reflex mechanism sufficiently complex to bring about the co-ordinated adjustment of the various sense organs to stimuli, and also to initiate the instinctive movements of the facial parts and body, which are interpreted as expressions of emotion. But these movements can all be accomplished without consciousness, and are apparently not acquirable in the lifetime of the individual. They represent instinctive or inherited reactions, simple if relatively few neurones take part in the co-ordination, complex and often apparently purposive if a greater number of neurones are involved. When to these neurones are added the neurones of the sensory areas of the cortex, of the association area, of the zone of language, and of the prefrontal lobes, the physiological problem is still merely the question of the anatomical connection of these neurones *inter se* and with the peripheral neurones. The evidence and the interpretation of what these neurones contribute to the production of complex bodily movements involve, however, two factors not necessary of consideration in connection with the functions of centres below the cortex, namely, the relation of consciousness to these processes and the development of acquired functions or habits.

Considered relatively, the functional activities of the cortex are largely the result of an ontogenic education, whereas those of the lower centres are the result of an inheritance of functions acquired in the course of organic evolution. But when anatomical and physiological connections have been established in a given adult brain, the physiological problem is then the same as before;—namely, "What additional complexities of movements are now possible from this additionally complex mechanism?" The existence in our minds of certain sensations due to the stimulation of particular areas may assist in establishing the functional relationships of these areas *inter se* and to lower centres, but the sensations themselves can form no part of a physiological explanation of the responsive movements that take place in consequence of such connections. The same principle must apply to the association centres as areas of higher psychical activity. The polite request "Please get off my toe" is as much a motor response of the peripheral neurones as the cry of pain. Experience shows that for the first reaction, certain cells of the cortex must have integral connection with the efferent pathway, which are not necessary for the much simpler movement. The psychologist cannot distinguish between perceptions and sensations as distinct entities, nor between intellect and imagination as diverse processes, nor does he regard the will as a faculty exclusive of other manifestations and processes of the mind. When it is maintained, therefore, that there are areas of higher level than the cortical sensory areas—first, an association area which is the anatomical *locus* for those cells whose functioning is responsible for the phases of consciousness distinguished by the terms knowledge, conception, imagination, thought; a second association area, the zone of language, which is the basis of the function of language as an intellectual and emotional instrument; and still a third region, the prefrontal lobes, which is essential for the preservation of high intellectual and moral character and for volitional effectiveness—it is not meant that these three centres contribute each a different mental element to consciousness, nor yet that they are the organs of three diverse mental faculties. The analysis suggests that a human being, who may manifest, at different times through speech, conduct, and bodily movement, intellectual capacity and moral character of different grades, must have these three areas intact, if he is to continue to evidence the highest attainment of which he is individually capable.

A question, often confusing, is frequently allowed to become involved with this psycho-physiological parallelism of increasing intellectual complexity and increasing integration of the cells of the central nervous system. On the one hand, the mere addition of neurones apparently forms a satisfactory explanation of the increased complexity of cortical reactions over that of the spinal reflexes. The psychical functions of the brain might therefore represent the result of a mere phylogenetic increase in nerve tissue, a product of cortical integration. On the other hand, in the human being and higher organisms, it is a common experience to find automatic actions developing from conscious actions, even becoming so set in the nervous system as to appear ineradicable reflexes. Many facts tend to suggest that conscious reaction has always presided over the phylogenetic development of reflex action; that psychical function thus preceded reflex function, and both helped to determine the course of organic evolution. This view was entertained by Cope, the eminent biologist, and is exploited as a fundamental philosophical hypothesis by Wundt, without doubt the leading psychologist of the day. Many difficulties present themselves to the acceptance of either theory. It is not necessary for us to take sides on this issue, when considering the localization of psychical function over the cortex of the cerebral convolutions; but it is desirable to keep this and similar psycho-physiological speculations from interfering with an acceptance of reported facts and conclusions.

It is not worth while to enter into a consideration of the various theories which have been propounded at different times to explain the specific nature of the nerve excitation which passes along the nerve fibres of a pathway of conduction. The crudest physical concepts have been called upon to do duty by way of explanation; thus the cell has been likened to a battery and the fibres to conducting wires; the nerve stimulus is frequently spoken of as a wave of nervous impulse, similar to but not identical with the electrical wave, propagated at an appreciable rate, flowing from nerve fibre to nerve fibre. Theories of electrical tension, of galvanism, of molecular vibrations, and of chemical explosions, are scientific fancies rather than hypotheses. When the nervous pathway was shown to be made up of unitary cellular elements, that were contiguous but not continuous, biological theory interpreted the conduction of the nerve stimulus as a series of amœboid movements. It may be said that no hypothesis has yet been formed that offers even the hope of becoming a sufficient explanation.

In addition to the original authorities, mentioned in the text, the writer has been much assisted by the critical abstracts of the literature to be found in the publications of Ferrier, Jackson, Macalister, Collins, Gordinier, and Barker, and especially by the "Sketches of the History of Reflex Action," by Hall and Hodge, in the *American Journal of Psychology*, from which have been drawn many statements of the established facts of the phenomena of reflex action. *Lightner Witmer.*

BRAIN, GROWTH OF THE.—The following article aims to present a general account of the growth changes which occur in the human brain and cord, between the time of normal birth and the natural end of life, thus including those found in old age.

In dealing, as in this case, with data for the most part very incomplete, the danger of confusion arises from the tendency, on the one hand, to make a general application of special observations, and, on the other, to interpret the *absence* of positive as equal to the *presence* of negative evidence. With these words as a preface, however, we may spare ourselves the duty of showing in special instances the limitations of the observations cited.

In discussing the changes which occur in the neuraxis (brain and spinal cord = central nervous system), the following outline is employed:

A. Growth changes in the neuraxis and some of its divisions.

B. Growth changes in the neuraxis—considered as the resultant of changes in the cells which constitute it.

1. Number of neurones.
2. Size of neurones.
3. Changes in the cytoplasm of the cell bodies during growth.

C. Growth of the cerebral cortex.

A. GROWTH CHANGES IN THE NEURAXIS AND SOME OF ITS DIVISIONS.—The human encephalon varies widely in weight at maturity, even when members of the same race and the same social class are alone compared. Differences in the final weight must be looked upon as resulting from differences in the process of growth. The weight of the encephalon at maturity is illustrated by the accompanying table based on the observations of Dr. Boyd:[1]

TABLE I. SHOWING IN GRAMS THE WEIGHT OF THE ENCEPHALON AND ITS SUBDIVISIONS IN SANE PERSONS, THE RECORDS BEING ARRANGED ACCORDING TO SEX, AGE, AND STATURE. (From Marshall's tables based on Boyd's records.)

SANE.

Males.					Females.				
Ages.	Encephalon.	Cerebrum.	Cerebellum.	Stem.	Stem.	Cerebellum.	Cerebrum.	Encephalon.	Ages.
Stature 175 cm. and upward.					Stature 163 cm. and upward.				
20–40	1409	1232	149	28	23	134	1108	1265	20–40
41–70	1363	1192	144	27	23	131	1055	1209	41–70
71–90	1330	1167	137	26	24	130	1012	1166	71–90
Stature 172–167 cm.					Stature 160-155 cm.				
20–40	1360	1188	144	28	26	137	1055	1218	20–40
41–70	1335	1164	144	27	26	131	1055	1212	41–70
71–90	1305	1135	142	28	24	128	969	1121	71–90
Stature 164 cm. and under.					Stature 152 cm. and under.				
20–40	1331	1168	138	25	24	130	1045	1199	20–40
41–70	1297	1123	139	25	25	129	1051	1205	41–70
71–90	1251	1095	131	25	25	123	974	1122	71–90

These records were obtained from 2,086 patients of the Marylebone Workhouse in London, representing, for the most part, the least favored class of persons native to Great Britain. For the purpose of weighing, the encephalon was divided into three portions: (1) The cerebrum, including all parts frontal to the midbrain; (2) the cerebellum, severed at the peduncles; and (3) the stem—the midbrain, pons, and bulb taken together.

Owing to the fact that these records are based on a workhouse population, it is probable that they represent brains less well grown and earlier subject to senile atrophy than would be the case among the more prosperous members of the community. The general relations to which we are about to call attention would, however, remain the same.

On comparing the sexes Table I. shows that the heavier brains belong to the males; on comparing those of different stature within each sex, that they belong to the tall individuals; and when those of the same sex and stature are compared, according to age, to those in the prime of life, *i.e.*, twenty to forty years of age. Sex and stature, then, are conditions which modify the weight which the brain will attain at maturity, and after the prime of life its weight diminishes.

Having indicated the weight at maturity under the conditions of the race and social class here chosen, we have next to determine the weight of the encephalon at birth, and the course of the changes by which it reaches its full size.

Vierordt has collected the most complete series of observations for the change in brain weight between birth and twenty-five years of age. The data are taken mainly from German records. They are printed in Table II.

Table II. To Show the Increase in Brain Weight with Age. Encephalon Weighed Entire with Pia. (Compiled by Vierordt.)

Age.	Males.		Females.	
	Number of cases.	Brain. Grams.	Number of cases.	Brain. Grams.
0 months	36	381	38	384
1 year	17	945	11	872
2 years	27	1025	28	961
3 "	19	1108	23	1040
4 "	19	1330	13	1139
5 "	16	1263	19	1221
6 "	10	1359	10	1265
7 "	14	1348	8	1296
8 "	4	1377	9	1150
9 "	3	1425	1	1243
10 "	8	1408	4	1284
11 "	7	1360	1	1258
12 "	5	1416	2	1245
13 "	8	**1487**	3	1256
14 "	12	1289	5	**1345**
15 "	3	**1490**	8	1238
16 "	7	1435	15	1273
17 "	15	1409	18	1237
18 "	18	1421	21	1325
19 "	21	1397	15	1234
20 "	14	1445	33	1228
21 "	29	1412	31	1320
22 "	26	1348	16	1283
23 "	22	1397	26	1278
24 "	30	1424	33	1249
25 "	25	1431	33	1224
Total	415		424	

When the data in Table II. are cast in the form of a curve representing the increase in weight according to age, we obtain the chart given below (Fig. 903).

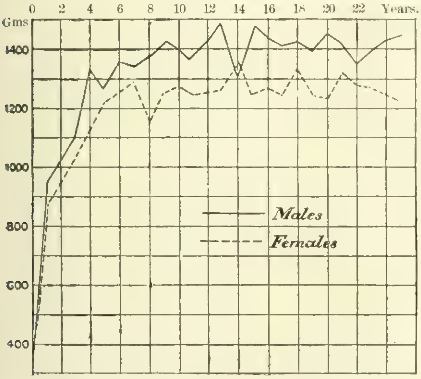

Fig. 903.—Curves Showing the Variations in Brain Weight During the First Twenty-Five Years of Life. Based on Table II.

In the records of Vierordt it appears that, except at birth and in the fourteenth year, the male has a greater brain weight than the female.*

In both sexes the most rapid increase in weight is during the first year; it continues to be rapid up to the fourth or fifth year, and then becomes slow till the seventh year, when the weight of the brain found in the adult is nearly attained. From this age on, there is a very slight and very slow growth up to maturity. At the time when nearly the final brain weight has been attained—namely, the seventh or eighth year—the full difference of 100 grams or more existing between the two sexes is evident. From this, it happens that the rapid growth of the brain has occurred while the body is still very immature, since boys of seven years weigh on the average only fifty pounds, and girls but forty-two pounds—this in both sexes being about one-third of the adult body weight; and that the differences characteristic of sex have been established before sexual maturity. The irregularities of the curve are to be explained as statistical mainly, and dependent on the comparative smallness of the number of cases available for each year. No significance is to be attached to the dip in the male curve at fourteen years. The very high averages for the males at twelve and fourteen years, and for the females at thirteen years, are to be noted, since they occur in other similar series.[5] These "premaxima" are most readily explained by assuming that an overgrowth of the brain during these years of beginning adolescence is one source of constitutional weakness, and hence the children dying at this period exhibit heavy brains. There is no reason to suppose that within the life cycle of the individual, the brain attains during these years a greater weight than that shown at maturity.

From the table of final weights (Table I.) as well as from that just presented on growth, it is plain that the difference in the weight of the encephalon according to sex is one exhibited at birth; that it increases during the growing period, and is maintained throughout life. In the first instance, this difference is most closely associated with the difference in the total body weight of the two sexes, and is so correlated in the mammalian series.

Table I. further shows us that the taller persons have the heavier brains, and this may probably be extended to mean the heavier persons, since when fairly compared, the taller are also probably the heavier. In old age in both sexes, the brain weight diminishes, as the result of shrinkage in the encephalon. There is some reason to think that this involutionary process is delayed in the more favored social classes.

It is an important fact that the differences in the weight of the encephalon according to sex, age, and stature are correlated with only very slight variations in the proportional development of the subdivisions of the encephalon as here examined. Table III. shows the percentage value of these subdivisions for different ages at all statures.

Table III. Showing the Percentage of Weight of the Subdivisions of the Encephalon, the Records being Grouped According to Age. Based on Table I.

Males.					Females.				
Age.	Encephalon.	Cerebrum.	Cerebellum.	Stem.	Stem.	Cerebellum.	Cerebrum.	Encephalon.	Age.
20-40	100	87.52	10.49	1.91	1.96	10.9	87.13	100	20-40
41-70	100	87.00	10.6	1.94	2.02	10.8	87.14	100	41-70
71-90	100	87.33	10.6	1.98	2.11	11.16	86.4	100	71-90

Here there is a very slight falling off in the proportional value of the cerebrum in persons of advanced age. In general the value of the male cerebrum is slightly in excess. In the next table (IV.), where the comparison is made according to stature, there is a regular decrease in the value of the male encephalon with diminishing stature, and at all statures the male cerebrum is slightly in excess of the female.

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* During the period of very rapid growth, a slight disparity in the average age of the cases compared easily reverses the weight relations according to sex. This is the probable cause of greater weight in the female at "birth," as reported by Vierordt. More careful determinations by Mies,[3] 1894, and Pfister,[4] 1897, show the male brain to be heavier.

TABLE IV.—SHOWING THE PERCENTAGE OF WEIGHT OF THE SUBDIVISIONS OF THE ENCEPHALON, THE RECORDS BEING GROUPED ACCORDING TO STATURE. BASED ON TABLE I.

MALES.					FEMALES.				
Stature.	Encephalon.	Cerebrum.	Cerebellum.	Stem.	Stem.	Cerebellum.	Cerebrum.	Encephalon.	Stature.
175 cm. and upward.	100	87.5	10.5	1.90	1.91	10.86	86.93	100	163 cm. and upward.
172–167 cm....	100	87.2	10.65	2.08	2.10	11.16	86.68	100	160–155 cm.
164 cm. and under.	100	87.17	10.6	1.86	2.09	10.83	87.06	100	152 cm. and under.

In Table V. it is possible to make the comparison of the proportional development of the several divisions from birth to old age.

TABLE V.—SHOWING THE PROPORTIONAL WEIGHT OF THE DIVISIONS OF THE ENCEPHALON AT DIFFERENT AGES. (Boyd.)

MALES.					FEMALES.				
Number of cases.	Age.	Cerebrum.	Cerebellum.	Stem.	Number of cases.	Age.	Cerebrum.	Cerebellum.	Stem.
45	New born.	92.4	5.8	1.60	45	New born.	92.1	6.2	1.50
22	7–14	87.8	10.3	1.61	18	7–14	87.9	10.5	1.50
99	30–40	87.3	10.6	1.98	80	30–40	87.0	10.8	2.01
95	70–80	87.0	10.7	2.09	128	70–80	86.9	10.9	2.15

We see here that the cerebellum is the portion least developed at birth, and that between birth and the seventh-year period, the proportions found at maturity are very nearly established. In this table, again, the percentage value of the cerebrum tends to be slightly greater for the male. During the active growing period the reduction in the percentage value of the cerebrum is due, of course, to the more active growth of the cerebellum and stem, while during the involutionary period—that is, between seventy and eighty years, in this table (V.)—the diminution in value is due to its more rapid shrinkage, as can be seen by examining the absolute weights exhibited in Table I.

As regards the subdivisions of the cerebrum, Franceschi[6] has some observations which are unique. He determined the weight of the thalamus and striatum for each half of the cerebrum, in a number of persons and at various ages. During the first five years, the records are too few and indefinite to be valuable. Beginning with twenty-one years, however, he has the following data to present:

TABLE VI.—GIVING THE WEIGHT OF THE BASAL GANGLIA IN THE TWO SEXES AT DIFFERENT AGES. WEIGHT IN GRAMS. (Franceschi.)

MALES (Basal ganglia).				FEMALES (Basal ganglia).			
Age.	Number of observations.	Mean weight.		Age.	Number of observations.	Mean weight.	
		Right.	Left.			Right.	Left.
21–40	16	41.2	40.8	21–40	20	36.0	36.0
41–70	38	41.6	42.3	41–70	45	37.7	38.0
71–87	22	42.4	42.4	71–87	21	37.7	41.0

This table shows no regular difference between the two halves of the brain. There is, however, a constant difference according to sex, these structures being about ten per cent. heavier in the male; and very curiously, an actual increase in weight in the last age group, when according to the other records the total weight of the cerebrum is *less* than that found during the prime of life. This peculiar relation must be confirmed before it can be regarded as significant.

In connection with the determination of the weight of the encephalon as the result of growth there are several problems arising from the effect of deformation of the skull during the growing period, and from the possibility of compensatory enlargement of the cranium along one or more axes when its normal growth is hindered. The winding of the child's head with a compressing bandage, so as to elongate it in the fronto-occipital axis, has for generations been practised about Toulouse, in France. The study of the brains of aged persons from this locality with skulls thus deformed has been made by Ambialet,[7] his investigation being the most important study along this line. As might be expected, the effects of this treatment are more pronounced if the deformation has been great than if moderate. Ambialet is able to show, first, that on the average the total weight of the encephalon was diminished, by this treatment, only from two to three per cent; further, that the relations between the cerebrum and the remainder of the encephalon were but slightly modified, the relative value of the cerebrum being reduced a fraction of a per cent., and, finally, that when the cerebrum is divided into lobes, after the method of Broca, the relative weights of these lobes are not significantly different from those found in the normal brain. Since the skulls in question are very evidently abnormal in shape, these results indicate that compensatory growth has occurred in the enclosed brain. This result would agree with those recently obtained from the study of crania by Boas,[8] which he formulates as follows: "Among skulls belonging to the same type, a breadth above the average is compensated by a height and a length below the average." This is probably only a special case representing a general tendency toward a final arrangement of cranial diameters which will result in the cranial capacity normal for the individual. The effects of bandaging the skull appear to cause a general nutritive disturbance rather than one limited by the boundaries of the bandage, and the results are not due to direct pressure on the enclosed brain. So far as this aspect of the problem is concerned, we have the beautiful researches of von Gudden[9] on the growth of the skull and brain, which show that while these two structures may to a slight extent mutually adapt themselves to each other, yet the fundamental growth changes in the brain are in a high degree independent of merely mechanical conditions.

In connection with the encephalon, we shall present such data as are available on the human spinal cord.

The weight of the cord at different ages can be best shown by a comprehensive tabulation of the results, though these are hardly numerous enough to be used for the formation of a curve (see Table VII.).

It thus appears that the spinal cord increases from an average weight of 3.42 gm. at birth to 27 gm. at maturity—an increase of nearly eightfold (7.8),—gaining in weight about twice as much as the encephalon. The encephalon has nearly attained its adult weight at the seventh year, while the cord (see table) at this time has less than two-thirds of its adult weight. So far as this table shows, the cord grows more rapidly than does the brain at *every period* succeeding birth. The final enlargement of the cord is correlated with the growth of the trunk and limbs that occurs during adolescence—a series of changes by which the cranial cavity is but slightly affected. The weight of the cord is therefore closely correlated with the length of the vertebral column. The proportion of the weight of the spinal cord to the weight of the brain is somewhat greater in men than in women, owing probably to the greater growth of the trunk in the male.

Since the central nervous system rapidly reaches nearly its full size while the remainder of the body is still quite small, it follows that the proportion of the weight of the entire body represented by it, decreases.

To show the relative development of the central ner-

TABLE VII.—WEIGHT OF THE HUMAN SPINAL CORD AT DIFFERENT AGES.

Observer.	Sex and number of cases.	Age.	Body.		Weight in Grams.		Grams of brain for each gram of cord.
			Weight. Grams.	Length. Millimetres.	Brain.	Cord.	
Mies	21 male and female.	Birth to 11 days				3.42 Range 2–6	10 males, 116. 11 females, 113.
Danielbekof	200 " " "	Average age, 30 days			Males 415.3 Females 399.2	3.9 3.8	Males 106. Females 104.
Mies	1 female	One year six months	4,856	667	730	7.74	94
"	1 male	Six years		1,060	1,234	16.88	73
"	1 female	Ten years nine months		1,330	1,189	17.28	69
"	1 male	Eighteen years six months		1,750	1,349	27.50	49
"	13 "	Mature				27 Range 24–33.3 gm.	10 males, 51. 4 females, 49.

vous system, as represented by the brain at different ages, the percentages below are given from Vierordt:

TABLE VIII.—PERCENTAGE VALUE OF THE BODY WEIGHT AS REPRESENTED BY THE ENCEPHALON AT THE AGES NAMED.

Age.	Brain Weight.	
	Male.	Female.
Birth	12.29	12.81
One year	10.50	11.39
Five years	7.94	7.98
Ten years	5.59	5.56
Fifteen years	3.62	3.09
Twenty years	2.43	2.31
Twenty-five years	2.16	2.23

This table shows that the proportional value of the central nervous system falls off rapidly during the growing, period and that the proportional value is greater in the female except in the ten, fifteen, and twenty year records. This greater proportional value in the female is the result of the smaller body weight, and the departure from this relation at the periods noted above is a statistical deviation, due most probably to the fact that during adolescent growth the increase in body weight occurs earlier in the female than in the male, and hence at these times the table compares the sexes at different phases of their growth.

In the growing neuraxis the changes in weight run nearly parallel to the changes in volume, but are a trifle more rapid, owing to the fact that with advancing age the specific gravity of the nerve substance increases and the percentage of water decreases.

Although there are numerous observations on the percentage of water in the human neuraxis at maturity, the changes occurring during growth have not been studied. To supplement this lack, a series of observations (not yet published) made on the white rat by Mr. Polkey and myself will be utilized.

From white rats at different ages the brain and spinal cord were removed separately, and the proportion of water in them was determined by drying, at about 97° C. A study of the results shows that at birth the brain contains about 87 per cent. of water and the cord 85 per cent., whereas in old age the brain contains about 78 per cent. and the cord 72 per cent. Thus a difference in the percentage of water exists between the brain and cord at birth, and this difference increases steadily throughout life.

In the case of both portions of the neuraxis, the curve representing the diminution in the percentage of water can be divided into three parts. The first part covers the first eight to ten days after birth. During this time the diminution in the percentage of water is slow. The second part comprises the next forty days of life. During this period it is very rapid. The third part is from the end of the second period to the termination of life, during which there is a very slow but steady diminution in the percentage of water.

The principal change in the central nervous system correlated with the proportional loss of water is the formation of medullary substance, and the two processes run very nearly parallel.

B. GROWTH CHANGES IN THE NEURAXIS CONSIDERED AS THE RESULTANT OF CHANGES IN THE CELLS WHICH CONSTITUTE IT.—The changes which occur in the central nervous system as a whole are but the resultant of all the changes taking place in the cells which compose it. An exhaustive list of these components would involve the cells forming the blood-vessels and the several sorts of supporting structures—ependyma, neuroglia, and connective tissue—in addition to the neurones proper. Lack of information concerning changes in the non-nervous structures will, however, preclude more than incidental mention of them, and we can turn our attention to the neurones, not, however, forgetting that the non-nervous structures are much more important constituents than this treatment of them would indicate.

1. *Number of the Neurones.*—It is first necessary to determine when the number of nucleated nerve cells (neurones, actual and potential) is fixed. The absence of karyokinetic figures in the human system at the time of birth is presumptive evidence that the number of nerve cells is not increased after that period. Other observations suggest that the production of new nerve cells has been completed in man by the end of the third month of fœtal life, and even if the production of new cells has not absolutely ceased at this time, our present evidence indicates that it has become very slow. It may be observed in passing, that in the white rat at birth cell division is still very active; but this has little bearing on the condition found in man, because the time of birth in different mammals does not furnish a base line for comparison, since the maturity of the animal at birth varies enormously with the species, and in this instance the new-born rat is to be compared with the human fœtus at least several months before birth. Granted that the number of nucleated nerve cells is formed early, we have next to inquire what happens to them after they have been formed. The studies of His[10] and others have shown that the first appearance of these elements is in the form of a neuroblast, which in some cases develops into the complete neurone, while in others it may remain undeveloped for years or even throughout life. When it does undergo development the order of the changes is in general that described by Cajal[11] for the cortical neurones (the pyramidal cells in the cortex of the rabbit). First, the formation of the axone, then the dendrites, and finally the collaterals; these portions being all well marked before the neurone as a whole has attained its full size. After this, the medullary sheath appears: first on the axone, and later on the collaterals. Nevertheless, even in those neuroblasts destined to undergo a complete development these changes do not occur at the same time in all the individuals. The fact that the sum of the nucleated cells which furnish both the permanent neuroblasts (granules of the authors) and the developed neurones is not increased after an early period in the fœtal development of man is the first important datum.

The second fact is that a number of these potential neurones begin to develop shortly after their formation, while others delay a longer or shorter time. Thirdly, all statements regarding the number of neurones (nerve cells) in any part of the nervous system are based on the number of fully characterized nerve elements there present, and leave unenumerated the potential nerve cells in the neuroblast stage. Since the well-characterized neurones are transformed from the neuroblasts only gradually and in series, it follows that during the earlier phases of growth the *number* of neurones will *increase;* but, as has just been explained, this increase is at the expense of neuroblasts already present in the locality, and does not depend on the *formation* of *new* cell elements.

From this it follows that in a given part of the nervous system there exists, after cell multiplication has ceased, the paradoxical conditions whereby an increase in the *number* of nerve cells may occur without any increase in the total number of neuroblasts and nerve cells taken together, since the latter arise by the transformation of the former.

In order to follow this increase in the number of neurones in the growing animal, it will be advantageous to use the following classification of the cell elements. By this classification, the neurones constituting the nervous system are arranged in three groups. Group I. The afferent neurones: Those furnishing the afferent pathways and having their cell bodies located in the spinal ganglia or their homologues. In this class the cell body lies outside the neuraxis. Group II. The central neurones—constituting the great mass of the central nervous system: All parts of these neurones lie within the wall of the original medullary tube, and all the neurones are concerned with the distribution of the impulses within these limits. Group III. The efferent neurones—concerned in distributing the impulses to the organs of expression. The type of the efferent neurone is the motor element of the ventral horn of the spinal cord, with its cell body within the wall of the medullary tube and its axone passing either to striped muscle tissue or to the peripheral neurones of the sympathetic system. To this last group the neurones of the sympathetic system also belong, but in this case both the cell bodies and the axones are found outside of the central system.

Since it is the mass of the central neurones which constitute the very great proportion of the central nervous system, and since this is the group which undergoes the greatest variation in the mammalian series, it has seemed desirable to separate this group from the other two, and this has been done by means of the foregoing classification. The studies of Birge[12] on the number of root fibres in frogs of different sizes and of Hardesty[13] on the growth of these fibres, show that in the afferent and efferent groups in the frog new axones are continually being formed, and we infer that this new formation follows from the development of neuroblasts which have remained latent for some time. The growth of the frog is so long continued that it is usually said to grow as long as it lives—a statement by no means demonstrated. The conditions are, however, very different from those found in mammals in which the period of growth is much more limited and the size of the body is fixed. In mammals, the available observations are very few. There are no observations on the increase of the neurones in the afferent system of the mammal (Group I.) except the recent study of the dorsal nerve root (fourth coccygeal of the cat) by Dale.[14] Here, the number of medullated fibres was found to be the same at different levels of the root, thus failing to show in the cat the outgrowing fibres revealed by Hardesty in the frog. It appears then that the number of dorsal root fibres in this locality is early fixed in the cat. Passing next to the efferent neurones, the records of Kaiser[15] on the "motor cells of the ventral horn" in the region of the human spinal cord, comprised between the fifth cervical and first thoracic segments, inclusive, are as follows:

TABLE IX.—SHOWING THE NUMBER OF DEVELOPED CELLS IN THE VENTRAL HORN IN THE CERVICAL ENLARGEMENT OF MAN AT DIFFERENT AGES. (Kaiser.)

Age.	Number of nerve cells.
Fœtus, sixteen weeks.	50,500
Fœtus, thirty-two weeks.	118,330
New-born child.	104,270
Boy, fifteen years.	211,800
Male, adult.	221,200

We assume, of course, in accordance with the explanation given above, that the additional neurones are derived from neuroblasts already present. If the numbers here given are interpreted literally, they mean that to the ventral roots of these segments there are added during the periods given the equivalent number of new fibres. Moreover, this addition, according to the table, would go on for a long period, and thus we might expect to find evidence of outgrowing axones in the ventral roots of persons more than fifteen years of age.

In the case of the ventral root of the fourth coccygeal of a cat, Dale was unable to find any evidence of outgrowing fibres; and, furthermore, the studies of Schiller[16] on the oculo-motor nerves of cats of different ages showed that at eighteen months the number of fibres present was hardly four per cent. greater than the number found at birth, indicating that here, at least, the number added between birth and maturity was small.

TABLE X.—SHOWING THE AVERAGE NUMBER OF FIBRES FOUND IN EACH OF THE OCULO-MOTOR NERVES OF CATS, FROM BIRTH TO EIGHTEEN MONTHS OF AGE. (Schiller.)

Age of specimen.	Mean number of fibres.	Extreme variation in number of fibres.
New born, A, B, C (average of three cases) ..	2,942	2,905-2,980
One month, D, E (average of two cases)	2,961	2,946-2,976
Four months, F	3,007	2,995-3,016
Twelve months, G (mother of A, B, F).......	3,013	3,002-3,019
Eighteen months, H	3,035	3,020-3,050

Using the observations of Schiller to control those of Kaiser, it may be argued that the number of efferent neurones in the cat is early completed. Probably the same is true for man; and if it is true for man then the great increase in the number of cell bodies found by Kaiser in the ventral horns of the spinal cord is due to the development of *central* rather than of *efferent neurones.*

Until more evidence on these points is available, however, further discussion would be useless.

The total number of neurones found in the brain and cord of man is doubtless variable, but for individuals of the same race the variability is probably not large. This is concluded from the constancy in the proportional development of the divisions of the encephalon. The closest determination of the number of neurones in the cerebral cortex of man has been made by Miss Thompson,[17] who employed as a basis the records of Hammarberg.[18] According to this computation, there are in the cerebral cortex 9,200,000,000 well-marked nerve cells. Using these results as a foundation, and estimating that in the remaining gray matter of the neuraxis the cells have an average frequency equal to that in the cortex, I have computed that the total number of nerve cells in the entire central nervous system is 11,200,000,000.

2. *Size of Neurones.*—In this connection it is important to remember that on passing down the mammalian series from larger to smaller forms, the nerve-cell bodies diminish much less rapidly in volume than does the entire animal or its central nervous system. From this it follows necessarily that in the nervous systems of small animals, with their small absolute weight and their comparatively large cell bodies, the number of the neurones must be far smaller than that found in man. To show the average size of the cell bodies in one locality in a

series of mammals, the following table from Kaiser is quoted:

TABLE XI.—SHOWING IN A SERIES OF MAMMALS THE MEAN DIAMETER OF CELLS FROM THE VENTRAL HORNS OF THE CERVICAL ENLARGEMENT. THE MEASUREMENTS FOR THE CHROMOPHOBIC AND CHROMOPHILIC CELLS ARE KEPT SEPARATE. (Kaiser.)

MEAN DIAMETER OF CELLS IN μ.

Chromophobe Cells.		Chromophile Cells.	
1 Plecotus auritus	28–53		
2 Talpa Europaea	36–54	1 Talpa Europaea	17–40
		2¹ Erinaceus Europæus	25–45
3 Cercocebus sinicus	33–60	3 Cercocebus sinicus	23–46
4 Cuniculus domesticus	41–61	4 Cuniculus domesticus	32–57.5
		5 Homo	23–59

1 Bat. 2 Mole. 2¹ Hedgehog. 3 Monkey. 4 Rabbit. 5 Man.

With this peculiarity of the cell bodies is to be contrasted the behavior of the axones. The calibre of the axones is most closely correlated with the volume of the cell bodies, and therefore is not more subject to diminution than the cell bodies themselves; but, on the other hand, the *length* of the axones necessarily varies with the size of the animal. From this it follows that the total volume of corresponding neurones is always diminished in the smaller animals, and this too despite the fact that the diameters of the cell bodies and the axones may be but little modified.

In man a notion of the volume of the average neurone at maturity can be obtained by dividing the volume of the central nervous system, so far as it is composed of neurones, by their estimated number. The volume obtained is 90,000 μ^3.*

The neuroblast, according to His,[10] has a volume of 700 cubic micra. According to this the average neurone would have increased only about one hundred and twenty-eight times in volume—whereas it can be shown that very many neurones increase more than a thousandfold.

Since a large number of neurones can be shown to increase many times more than the average enlargement, it follows that there must be a very large number of neuroblasts which develop either slightly or not at all. In support of this statement, attention is called to the fact that in the cerebral cortex the smallest neurones have diameters much smaller than that of the original neuroblasts; while in the cerebellar cortex, the granules with a mean diameter of about 7 μ appear still more reduced. There is at present no satisfactory explanation for these cases.

The only observations on the changes in the volumes of growing cell bodies in man are those by Kaiser,[15] made on the cell bodies of the ventral horns of the cervical enlargement of the spinal cord.

TABLE XII.—SHOWING THE VOLUMES OF THE LARGEST CELL BODIES IN THE VENTRAL HORN OF THE CERVICAL CORD OF MAN. (Based on Kaiser's records of the mean diameters.)

Subject.	Age.	Proportional volume of the cell bodies. 1 = 700 μ^3.†	Time interval.
Fœtus	Four weeks	1	36 weeks.
"	Twenty weeks	17	
"	Twenty-four weeks.	31	
"	Twenty-eight weeks	67	
"	Thirty-six weeks	81	
Child at birth		124	15 years.
Boy, fifteen years.		124	
Man, adult		160	15 years.

† The volume 700 μ^3, in the fœtus of four weeks, is taken from His, and the figures represent multiples of that volume.

The proportional volumes given in Table XII. show that the rapid enlargement of these cell bodies occurs before birth. It gives, however, the same values for the child at birth and the youth at fifteen years, while in the mature man the size is somewhat greater. This is so peculiar a result that one is inclined to give greater weight to the statements of Marinesco,[19] who finds the cell bodies in question to increase in diameter from their formation up to twenty-five or thirty years, and the giant cells of the cerebral cortex to enlarge for a still longer time.

Opposed to Kaiser are also my own observations on the white rat, where the growth of the cell bodies continues, though at a diminishing rate, up to maturity. It appears from the white rat that the enlargement of the cell bodies is an event that takes place early, in the first half of the period of rapid growth of the neuraxis (first fifty days of life), and that it is mainly accomplished at a time when the axones are still increasing in all dimensions, and when medullation is yet very incomplete. The central nervous system in its first embryonic form is a mass of neuroblasts; in its completed form it is composed mainly of axones and their medullary sheaths. The condition at maturity was brought out by investigations of Miss Thompson,[17] on the proportion of the cerebral cortex occupied by the bodies of the neurones. The observations were made on material hardened in alcohol and stained with methylene blue (Hammarberg [18]). The cell bodies, under the conditions chosen, represented only 1.37 per cent. of the entire volume of the cortex. If we should increase this to 3 per cent. and include the dendrites with the cell bodies, there would still remain 97 per cent. of the cortex composed of other substances, and in a large measure this 97 per cent. would be represented by medullated axones. All the white substance of the nervous system is, in even a greater measure, composed of the same constituents, so that, taken all together, the medullated axones form the great proportion of the entire system. For this reason at least, this division of the neurone (the axone) requires special consideration. There is in the first place no reason to assume that the relative size of these structures is exactly the same in two brains otherwise comparable. But owing to their great preponderance a slight variation in the size of all the axones and their sheaths might alter very decidedly the gross weight of the encephalon without at the same time necessarily adding to its physiological complexity (Donaldson [20]). It is easy to see that even among the central neurones,—as, for example, the pyramidal cells of the cerebral cortex, the axone of which reaches to the lumbar enlargement of the spinal cord,—the axone with its sheath must be many times the volume of the cell body. The medullated axones of the large pyramidal cells are of such a diameter that a length of about 0.5 mm. of axone is equal in volume to the cell body. This gives twenty times the volume of the cell body for each centimetre of the medullated axone, and if it extended 40 cm. we should have the cell body with (20×40) 800 times its volume as represented by the medullated axone.

In the peripheral nervous system the relative mass of the axones is even greater than in the central system. Observations on the white rat show that in the case of the largest neurones belonging to the mid-lumbar spinal ganglia, there is a direct correlation between the increase in volume of the growing ganglion cell body and the area of the cross section of its axone; the ratios of enlargement being similar for both.[32] Further, from the time when the medullary sheath is formed on the axones of these cells up to maturity, this sheath exhibits in cross section a simple and constant relation to the enclosed axis—viz., the area of the enclosing medullary ring being very nearly equal to the area of the enclosed axis. This same relation between axis and sheath appears in the peripheral system of man, but the relation existing in the central nervous system has not yet been determined. As to the calibre of the medullated axones in the peripheral system, Westphal [21] reports in the peripheral nerves of man at birth the smallest fibres, including the sheath, 1.2 to 2 μ in diameter, and the largest 7 to 8 μ with an average diameter for all of 3 to 4 μ, while in the adult the large fibres are from 10 to 15 μ in diameter. From the third to the sixth week the myelin becomes more abundant and the fibres double in diameter. In the eighth month there are still some unmedullated portions in the nerves, but these gradually disappear.

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* The estimated number of neurones—excluding the spinal and sympathetic ganglia—is 11,200,000,000. The volume of the central nervous system, composed of neurones = 1,005 c.c. The individual neurone, therefore, has the volume given above.

There is no fixed relation between the *volumes* of the cell bodies and the *length* of the axones which they produce.

In the frog Dr. Dunn[22] has shown that the fibres of greatest diameter in the sciatic nerve pass to innervate the muscles and skin of the thigh, while those going to the parts of the frog's leg below the thigh have a smaller average diameter, as well as being individually of less calibre. In this instance, therefore, the fibres of larger calibre tend to run the shorter course.

Looking upon the three groups of neurones as elements modified to receive stimulation, and to transmit impulses, it is found that the afferent neurones (Group I.) increase on the receptive side mainly by the expansion of their peripheral axones in the skin and muscles; that the cell body is practically devoid of dendrites receiving but few stimuli, and that their field of influence is determined by the extension of the proximal axone within the central system. The central neurones (Group II.) extend their receptive side by the multiplication of the dendrites, and their discharging side by the extension and ramification of their axones; while the efferent neurones (Group III.) extend their receptive side by the multiplication of their dendrites within the central system, and on their discharging side influence a greater or less mass of muscle or of sympathetic neurones according to the ramifications of their axones.

From this it will be seen that the complexity of the central nervous system depends first on the ramification of the proximal axones of Group I., second on the ramifications of both the dendrites and axones of Group II., and finally on the ramifications of dendrites alone in Group III. It is to this complexity that the growth changes in the neurones ultimately contribute, and there already exist very suggestive observations by Athias[23] showing how the growth of the dendrites of the Purkinje cells and of the terminals of the "climbing fibres" are correlated. During growth the cell bodies may also change in shape apparently under mechanical stress. In those parts of the spinal cord like the cervical and thoracic regions, where the segments of the cord lengthen with the growth of the vertebræ, the axes of the mature cell bodies tend to be drawn out parallel to the long axis of the cord; whereas in the lumbar region of the spinal cord, where the segments remain short, the bodies of the efferent neurones are more nearly equiaxial.

As the spinal cord increases in weight, the central canal also becomes larger. This involves (in the case of the white rat) a large extension of the wall of the canal, formed by the ependyma cells. Measurement of the ependyma cells shows that the individual elements increase but very slightly in their diameters, and hence the great increase in the wall must be due to the insertion of new cells. It seems probable, moreover, that the ependyma lining the other cavities of the neuraxis is extended by a similar process.

Neurones in Old Age.—As a rule the life of the neurone is coterminous with that of the individual. There is, however, evidence that some neurones die before the individual dies, but no evidence shows that new elements take the place of those which thus perish.

Old age in man is accompanied by a loss in the gross weight of the encephalon. This has not yet been demonstrated in animals. In the white rat, however, old age is correlated with the smallest percentage of water found. Systematic studies on the white rat show that in old animals (three or more years) the cell bodies in every division of the neuraxis are shrunken when compared with the corresponding elements during the prime of life. Casual observations on man suggest the same changes, though they are well demonstrated only in the spinal cord. Hodge[24] found in a man of ninety-two years a diminished number of Purkinje cells in the cerebellar cortex, and in the spinal ganglia the cell bodies and nuclei were shrunken, the nucleoli absent from all but a few cells, and the cytoplasm was loaded with pigment. The coarse changes in old age appear, therefore, in the cell bodies and their parts—while the finer changes will be brought out when the alterations in the cytoplasm with age are described. We should further expect in old age a loss of physiological connections between the separate neurones, but this has not been demonstrated.

Changes in the Cytoplasm of the Cell Bodies during Growth.—The studies of Marinesco[19] and Biervliet[25] show that in the large cell bodies of the efferent group in the ventral horns of the spinal cord the "stainable substance" of Nissl is fully formed at birth—the other portions of the cytoplasm being correspondingly well differentiated. This does not mean that this stainable substance is formed in *all* these cells at this time, but only that those neurones which have first developed have already attained this differentiation. The process repeats itself as the neuroblasts, with longer latent periods, gradually enlarge. The neurone in its first embryonic stages stains by the Nissl method so as to reveal a faint blue tint evenly distributed in the cytoplasm. As the element grows, the blue tint becomes denser at the periphery of the cell body. Here discrete particles, stained intensely, appear, and these, increasing individually in size, also form a wider band which spreads toward the nucleus. As the features of the mature cell become more evident the diffuse blue tint disappears, as though the constituent capable of that reaction had by degrees become concentrated in the masses of stainable substance. This process of the formation of stainable masses is carried farthest in the largest cell bodies—for example, in the large cells of the spinal ganglia; those of the ventral horns of the cord and the large pyramids of the cerebral cortex. The smaller cells of the neuraxis exhibit varying degrees of a less complete formation of the stainable substance, representing in their final condition phases through which the largest cells have already passed. In old age the neurones undergo involutionary changes one at a time. The masses of stainable substance become disorganized; the changes progressing from the centre or nucleus toward the periphery. When this occurs, a black or yellow pigment-like substance, often in very fine grains, appears to take the place of the masses destroyed. In the ventral-horn cells true pigment is to be found about the twentieth year, though it comes much earlier in other portions of the neuraxis. With the destruction of the stainable substance, the cell body, as well as the nucleus and its contents, tends to shrink and to stain less strongly.

In correlating growth with function, it is often stated that a neurone which is destined to become medullated does not become functional until its medullary sheath has been acquired. The young white rat, in the nervous system of which there is at birth not a medullated fibre, is a sufficient contradiction to this dictum. It is admitted, nevertheless, that in general the appearance of functional adjustments runs parallel with the medullation of the neurones by which those adjustments are mediated; but the two events do not stand in a strict causal relation. The same is true of the stainable substance of Nissl in the cell body, where the formation of well-marked masses is characteristic of full development and full functional power, without being absolutely necessary. By prematurely exposing to light the eyes of young rabbits, the optic nerves of which were unmedullated, Held[26] was able to hasten the formation of the medullary sheath in the stimulated animals. Just how this experiment should be interpreted is not perfectly clear; but if we consider it as due to exercise, then the unmedullated fibres must, in spite of statements to the contrary, have been capable of being exercised even before they acquired their sheaths. Beyond this experiment there are no data on the effect of activity on the growth processes in the central nervous system. In this connection we recall that the encephalon has attained very nearly its full weight at seven years, that is, at a time before any formal school training has begun. If this is granted, then the subsequent functional powers which the child may attain are correlated with a very small addition of substance to the encephalon. This seeming paradox disappears, I think, when the very small volume of the cell bodies in the central system is considered (27.2 gm.), and when it is remembered how a very slight additional weight of material could be so disposed as to add greatly to the physiological complexity of the system.

Judging by every-day experience, it appears that favorable growth conditions have their effect more in prolonging the growth changes that have once been initiated than in hastening prematurely the onset of any given set of changes, and that when growth is hindered, there often appears in the individual a "prematureness," which we might call precocity, if it did not tend to become permanent in spite of increasing age, and thus in later years show itself in its real form as an arrest of development.

C. GROWTH OF THE CEREBRAL CORTEX.—Despite the great interest which attaches to changes in the cerebral cortex, our information is very imperfect. In one locality in the white rat, on the lateral aspect of the hemisphere at the level of the optic chiasma, the thickness of the cell layer increased as follows between birth and maturity:

TABLE XIII.—WHITE RAT THICKNESS OF CELL LAYER OF CORTEX IN MILLIMETRES.

Weight of rat in grams.	Age.	Thickness of cell layer.
4.6	Birth	.40
10.4	Ten days	.82
25.7	Twenty days	1.32
68.5	Fifty days	1.37
159.2	Maturity	1.49
242	Old age	1.36

The data on the change in the thickness of the human cortex are contradictory, some observers claiming that it actually becomes thinner with age. For this reason we omit a discussion of this point and pass to the determination of the increase in the medullated fibres, which all investigators have found.

The general course of the development of the fibre systems of the human cerebral cortex is described in the following way by Kaes,[27] and we here quote from a summary of his observations given by Miss Thompson.[31] For the stages earlier than one and one-quarter years, Kaes relies on the observations of Vulpius,[28] but the subsequent history is based on his own investigations. The first group of fibres to become medullated are the cortical projection fibres. At birth these appear raying out almost as far as the cortex. At about four months the fibræ propriæ, the first of the cortical association fibres, become medullated (Fig. 904). At about eight months the first of the intracortical fibres begin to be medullated in those regions which are most advanced. The description of the further development cannot be accurately assigned to definite ages, partly because some regions of the cortex develop so much more rapidly than others, and partly because Kaes examined no brains between the ages of one and one-quarter and eighteen years. A general description of the course of events can, however, be easily derived from a comparison of the different stages of advancement within the same brain. The first cortical fibres which develop shortly after the fibræ propriæ are a few scattered fibres running parallel to the layer of the fibræ propriæ on its ectal border. Gradually these latter increase in number, spread for a short distance toward the surface of the cortex and assume a stratified appearance. These form the beginning of the "outer association layer" of Kaes. Before the formation of the outer association layer is completed two other sets of fibres appear; one of these surrounds the outer limit of the projection fibres, which by this time have completed their normal growth into the cortex. This is the Baillarger or Gennari layer. It marks the ectal border of the outer association layer, but is composed of fibres of larger calibre than the remainder of that layer. The second set of fibres which appears at this period is the zonal layer, at the ectal border of the cortex and immediately beneath the pia. It also is composed of fibres of large calibre. The stage of development just described is characteristic of the advanced portions of the cortex in a child of one and one-quarter years. Its distinctive features are, in brief, a partly formed outer association layer, consisting of some stratified fibres lying next the fibræ propriæ, and the Baillarger layer at its ectal border. At this stage these two portions of the outer association layer are separated by a region free from medullated fibres. On its ectal side the Baillarger layer is separated from the zonal layer by a second region free from medullated fibres, the region corresponding to the "II. and III. cell layers" of Meynert.

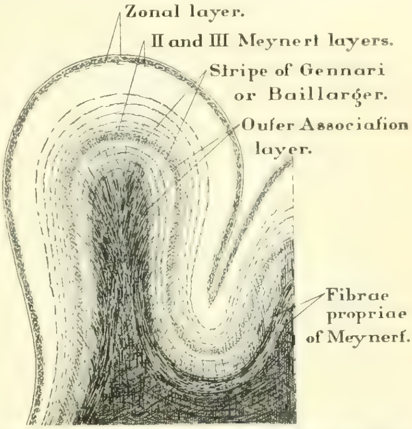
Zonal layer.
II and III Meynert layers.
Stripe of Gennari or Baillarger.
Outer Association layer.
Fibrae propriae of Meynert.

FIG. 904. Semidiagrammatic Representation of the Cortical Fibres in a Section of the Occipital Cortex of a Male Child of One and One-Fourth Years. (From Theodore Kaes, 1894. The designations are the same as those used in Kaes' papers.)

As development continues, the layer formed by the outer association fibres spreads gradually toward the Baillarger layer until it reaches the latter. At the same time the Baillarger and zonal layers grow broader and richer in fibres. The next stage is marked by the appearance of the inner Baillarger layer, and of the first fibres of the II. and III. Meynert layers. The inner Baillarger layer appears as a narrower line of coarser fibres among the fine fibres of the outer association layer, just ental to the outer Baillarger layer.

The fibres in the II. and III. Meynert layers are the finest of the cortex. The first of these to become medullated are those lying nearest the outer Baillarger layer. From the region of its first appearance, this layer (II. and III. Meynert layers) gradually extends ectad, and this process continues until these fibres meet those of the zonal layer. The final stage in the development of the cortex is the addition of a secondary system of coarse fibres to those which have been already described. The fibres of this secondary system are first seen in the outer association layer. Shortly afterward fibres of the same sort are found scattered through the II. and III. Meynert layers. At first these appear singly, but later are organized into a stratum which Kaes identifies with "Bechterew's streak." Still later, similar fibres appear in the Baillarger layer, and in the most highly developed cortex known they appear as a secondary system of coarse fibres generally distributed through its entire thickness. Very few regions of the cortex reach this highest stage, however, even in the fully grown adult. The period from youth (eighteen years) to maturity is in general characterized by the gradual appearance of the fine fibres in the II. and III. Meynert layers, and the formation of the secondary fibre system of coarse fibres; but in the fully grown cerebrum there are regions which do not reach even the stage at which the fibres of the II. and III. Meynert layers become medullated.

The central gyri exhibit the most highly developed fibre systems. The addition of new medullated fibres may continue, according to Kaes, up to the fiftieth year of life, though this limit must certainly be subject to wide individual variations.

Flechsig[29] has shown that the cortico-petal projection fibres first became medullated in the regions of the cortex, which mediate sensations, and thus by following the process in these fibres, the sensorimotor areas of the cortex can be mapped out. Their demarcation occurs within the first three months after birth. The intervening portions of the cortex form the association centres of Flechsig and develop later. In the great sensorimotor region about the central fissure Passow[30] has been able to show that the association fibres are at maturity best developed in the more ventral portion which contains the (discharging) pyramidal cells controlling the movements of the lower arm, hand, and face. In the child at one and one-quarter years this layer is equally developed through the length of the gyri, that is, there is no differentiation between the cell groups controlling the leg and the proximal portions of the arm and those which control the distal portions of the arm, and from this we infer that the cortical control of the finer muscles and finer movements increases for some time after that for the coarser movements has been completed.

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BRAIN, HISTOLOGY OF.—METHODS.—The nerve tissues of the brain may be studied fresh or in frozen section, by maceration and isolation, or after hardening by various methods.

Fresh Tissues.—Nervous tissues from animals can be obtained immediately after death. In human beings a certain number of hours practically always elapse before the material can be removed from the body. Certain post-mortem alterations occur early, particularly in the most labile constituents of the nerve-cell protoplasm. But for ordinary histological purposes tissue obtained from the central or peripheral nervous system within twelve hours after death, provided the body has been kept cool, is sufficiently fresh for minute microscopic examination. For many studies, too, tissue removed as late as twenty-four hours after death, provided the body has been kept cool, is quite satisfactory, though one should be sceptical in such tissue in drawing conclusions from the condition of certain of the microscopic pictures, for example, those of the Nissl bodies, and the so-called fibrillary structures.

In examining fresh tissues either teased particles or sections made by the double knife of Valentine may be employed. The teasing method is particularly applicable to the study of the peripheral nerves. These may be observed in an indifferent fluid like physiological salt solution or blood serum, or after the addition of some reagent (acetic acid, osmic acid, caustic potash). Sections of entirely fresh tissue made with the double knife of Valentine are very fragile, besides being extremely difficult to prepare. They may be examined in physiological salt solution, care being taken that the cover slip is not pressed upon. Ehrlich's method of staining fresh masses of tissue will be referred to later.

Maceration and Isolation.—For the isolation of histological elements, especially in the central nervous system, the use of some macerating fluid is desirable. A large number of these have been employed, but only the more important ones need be mentioned. Osmic-acid solutions (one-tenth of one per cent.) work well, any fatty structures, including of course the myeline sheaths, being stained of a dark color. Müller's fluid and dilute chromic-acid solutions (one-one-hundredth of one per cent. to four-one-hundredths of one per cent.) are useful macerating reagents provided the fluids are not allowed to act too long. Tissues macerated in these solutions should be teased and examined at the end of twenty-four hours. Ranvier's alcohol (thirty-three and one-third per cent.) yields very good results.

The tissues intended for maceration should be divided into small pieces before being placed in the macerating fluid. At the end of the period of maceration gentle shaking in a test tube often facilitates the isolation of elements. A pipette may be used for transferring minute particles suspended in the fluid to the microscopic slide for examination. Coarser particles may be teased upon the slide or squeezed between the cover slip and the slide.

The fluid used for maceration may be employed as a mounting medium for the microscopic observations, but as a rule it is better to render the tissues somewhat transparent. For this purpose dilute solutions of acetic acid (one per cent.), saturated aqueous solution of potassium acetate, diluted glycerin, or salty glycerin may be used.

Hardened Tissues.—The three fluids most frequently employed at present for the hardening of nerve tissues are: (1) Müller's fluid, (2) alcohol, and (3) formol.

Müller's Fluid. This hardening reagent consists of potassium bichromate, 2.5; sodium sulphate, 1; distilled water, 100. If desired the sodium sulphate may be omitted, simple solutions of bichromate of potash appearing to act as well as the fluid prepared according to the original formula. Müller's fluid should be changed frequently during the hardening process. Hardening in this fluid requires from several weeks to several months at the ordinary temperature, though if the tissues be kept in the fluid in a thermostat at the body temperature the process may be much shortened. In summer the fluid is particularly prone to become contaminated with growths of fungi. This may be prevented by the addition of a small quantity of camphor. After Müller's fluid hardening, the tissues are best prepared for embedding by dehydration in alcohol, as a rule without previous washing out in water. Tissues hardened in Müller's fluid stain well in carmine and with Weigert's myeline stain. They are not suitable, however, for the application of finer histological methods, such as that of Nissl.

Alcohol. This reagent should be employed when the original Nissl procedure is to be applied, small pieces of the tissue being left in ninety-five-per-cent. alcohol for about three days (see Nissl's method). Alcohol hardening is also desirable if Weigert's fibrin stain or Gram's method of staining bacteria is to be utilized. The periphery of bits of tissue hardened in strong alcohol is likely to undergo marked contraction and distortion. The blood at the periphery of such tissue is also much altered. Artefacts in various parts of the tissue may result from the action of the alcohol.

Formol. At present solutions of this substance are much employed in neurological technique since tissues fixed in them can be stained by several different methods. Formol, or formalin, is a forty-per-cent. aqueous solution of formaldehyde. As a rule, ten-per-cent. solutions of formol are used for hardening pieces of the central nervous system. This corresponds to a four-per-cent. aqueous solution of the gaseous formaldehyde. The whole brain may be hardened more or less satisfactorily in such a solution, but it is better, as a rule, to more or less subdivide the organ. Formol does not contract the tissues hardened in it, but fixes them rapidly in their original form, thus differing markedly from many other hardening fluids. The fluid has a characteristic odor and gives off irritating fumes. Injury to the eyes must be carefully avoided when using it, and it is also well to keep the hands as much out of the fluid as possible, as sometimes a troublesome form of dermatitis is set up by it. After hardening in formalin for a few days the tissue is ready for further manipulation. If Weigert's myeline stain is to be employed the tissue may be placed in Müller's fluid or his chromic acid mordant. The latter also suffices for the application of Weigert's neuroglia stain. Formalin tissues can also be used for studies by Marchi's method; the ordinary Marchi procedure is gone through with after the formalin hardening. Tissues prepared in formalin do not warp so much as those simply hardened in Müller's fluid. Very good Nissl preparations can also be made from formalin tissues provided they have been gotten fresh and cut into small pieces. The results are not equal, however, to those obtained after fixation in alcohol or sublimate. Marini's modification of the formalin hardening is especially recommended when it is desired to examine tissue by several different methods. This investigator recommends a fluid consisting of five per cent. formol with one-tenth of one per cent. chromic acid in ninety per cent. alcohol. Large pieces of the tissue put into this fluid for twenty-four hours are then removed and divided into small pieces. The latter are placed in more of the fluid freshly prepared, which is changed every day for from three to five days. The blocks of tissue are then fastened upon cork (without any other preparation), and kept in ninety-per-cent. alcohol or in a one-per-cent. solution of chromic acid in ninety-per-cent. alcohol. Sections for staining with methylene blue or thionin are placed in ninety-per-cent. alcohol; those for Weigert's myeline stain in Müller's fluid or in a three-per-cent. solution of potassium bichromate, while sections to which Weigert's method for studying neuroglia is to be applied are placed in a solution of chromogen.

When the material to be studied is not limited in amount it is preferable to use at least three hardening fluids: (1) alcohol for Nissl's method; (2) formol for Weigert's myeline stain, for Marchi's and for Golgi's methods; and (3) Weigert's formol-chrome-alum mordant for the neuroglia stain.

Sublimate solutions, Orth's fluid, Erlitzki's fluid, Flemming's mixture, Van Gehuchten's fluid are all recommended for special purposes. The formulæ for these fluids are to be found in the text books of histological technique. (See also article: *Histological Technique.*)

Embedding.—Three methods are ordinarily employed for embedding neurological tissues: (1) embedding in pith or gum; (2) celloidin embedding; and (3) paraffin embedding.

Pith or gum embedding may be dispensed with. Nissl, for his method, insists upon the avoidance of embedding entirely. He simply fastens the mass of tissue to the block by a solution of gum arabic. He fears that celloidin or paraffin embedding will interfere with the structure of the protoplasm of the nerve cells. He is here in error. Careful embedding in celloidin or paraffin, especially the latter, preserves beautifully the structure of the protoplasm.

Celloidin embedding is carried out as follows: After dehydration in absolute alcohol the tissues are left for twenty-four hours in equal parts of absolute alcohol and ether. They are then transferred to a very thin solution of celloidin dissolved in alcohol and ether. Here they remain until the thin fluid has penetrated the tissue. Small blocks are sufficiently penetrated if they remain for from two to five days. Large pieces, however, as, for example, a whole hemisphere of a baby's brain, must remain in a thin celloidin for a much longer time. The tissues are next transferred to a solution of celloidin which has the consistency of thick syrup. They need not remain in this fluid long; twenty-four to forty-eight hours suffice. There is a widespread idea that the longer tissues stay in thick celloidin the better are the sections obtained. The reverse rather is true, especially when we have to deal with large pieces. The penetration by the thin celloidin should, however, be complete. The thick celloidin may be allowed to stiffen very gradually through evaporation of the alcohol and ether, and a block of it containing the tissue be fastened by means of celloidin on a piece of cork or wood. Or it may be placed directly, without previous stiffening of the celloidin, on a block, allowed to stand in the air for a few minutes until the surface of the celloidin has hardened, after which it may be immersed in eighty-per-cent. alcohol. The blocks may be kept in eighty-per-cent. alcohol until the sectioning is carried out. Instead of celloidin, photoxylin may be employed if desired; it is more transparent than celloidin.

Celloidin embedding is to be preferred when large pieces of tissues are handled, when the tissue is friable, or when the staining method to be employed is one involving considerable manipulation. It is always to be used when Weigert's myeline stain is to be applied.

For embedding in paraffin small pieces should be taken, thoroughly dehydrated in absolute alcohol (twenty-four hours), cleared in xylol or chloroform, and then passed through equal parts of the clearing reagent and soft paraffin, thence into melted paraffin (melting point of 52° C.) for two to eight hours, the paraffin being changed twice during this period. After complete penetration by the paraffin, best in the thermostat kept at the melting point of the substance, the piece of tissue is placed in a shallow dish and covered with paraffin. This is rapidly cooled with cold water until the paraffin stiffens, after which the paraffin block, properly trimmed, can be fastened on the platform of a microtome, when it is ready for cutting.

In warm weather it may be necessary to use a paraffin of higher melting point (60° to 65° C.); in cool weather, a paraffin of low melting point will be found useful (45° to 50° C.). If two kinds of paraffin, very soft and very hard, be kept in stock, it is easy, by mixing them in variable proportions, to make a paraffin of any desired melting point.

Paraffin is to be preferred when very thin sections are desired, or when staining *in toto,* before embedding, is possible. It is especially useful, therefore, in the study of the embryology of the nervous system, and also in the investigation of the finest histological details of the neural elements. It is one of the best methods which can be used when Nissl's method is to be applied.

A combination of the celloidin and paraffin methods may sometimes be used with advantage. The tissue after dehydration is passed through equal parts of absolute alcohol and ether and then soaked for twenty-four hours in a solution of celloidin. The object is then cleared in oil of origanum, after which it is to remain in a mixture of oil of origanum and fluid paraffin for one or two hours at a temperature of 40° C. It is then placed in melted paraffin of a melting point suitable to the temperature of the time of year and embedded in paraffin in the ordinary way. Now that methods of fastening paraffin sections to the slide have been very much improved, this combination of celloidin and paraffin is very little in vogue.

Sectioning.—In making sections of nervous tissue we have to consider: (1) frozen sections; (2) sections after celloidin embedding, and (3) sectioning after paraffin embedding.

Frozen sections may be made of fresh tissues or of tissues which have been hardened in Müller's fluid or formalin. Frozen sections should be very thin, since to get the most out of them they have to be studied with high powers of the microscope, and unless the sections are thin this is of course impossible. An ether-freezing microtome may be employed, or, better still, a carbon-dioxide freezing microtome. If fresh tissues are used they should be transferred from the knife to physiological salt solution and mounted on a slide in the same fluid; if they have been fixed in formalin or Müller's fluid before freezing they may be examined either in Müller's fluid, Farrant's medium, or salty glycerin.

Celloidin Sectioning.—The sections may be made with any good microtome. The microtomes made by Bausch & Lomb, by Schanze, and by Jung are good. The knife must be kept very sharp, and it is important to have it constantly flooded with eighty-per-cent. alcohol. The whole edge of the knife should be made to cut from the heel to the tip. If very large sections are to be cut, it is best to use a microtome which is so arranged that the knife and tissue mass are entirely immersed in alcohol. Such microtomes are now available at a moderate cost. If sections of a whole hemisphere are to be made, it is important that the knife should be clamped at both ends; otherwise the vibration of the blade will lead to streakiness or even more marked irregularity in the thickness of the sections.

Serial sectioning in celloidin is quite possible if care be taken. The most convenient method is that employed by Obregia. The glass slides upon which the sections are to be employed are coated twenty-four or forty-eight hours before they are to be used, with the following solution: 30 c.c. of a thick syrup made by dissolving powdered candy sugar in boiling distilled water is mixed with 10 c.c. of a thick solution of pure dextrin in distilled water and 20 c.c. of absolute alcohol. The glass slides after partial drying are quite sticky. On a large white plate two or three thicknesses of good toilet paper are thoroughly moistened with eighty-per-cent. alcohol; on the toilet paper an area is marked off in lead pencil which corresponds to the size of the large cover glass which is to cover the preparations on the slide. Each celloidin section, as it is cut, is taken up from the knife on a strip of moist toilet paper and transferred by means of this to the plate. Some regular arrangement of sections in the area marked off on the plate is to be maintained. When the area is full of sections the sticky side of the prepared glass slide is pressed firmly down upon the series of sections. On lifting the glass slide all of the sections adhere to the glass slide. With a sharp knife the celloidin protruding beyond the edge of the glass slide is trimmed off. After a moment's drying to permit any excess of alcohol to disappear, a thin solution of photoxylin is poured over the sections on the glass slide, care being taken to have the photoxylin solution evenly distributed. For this latter purpose it may be desirable to use a glass plate carefully levelled, upon which the glass slide may be laid, while the photoxylin is stiffening. As soon as the photoxylin has stiffened on the surface the glass slide with the sections now covered by a thin sheet of photoxylin can be thrown into a large dish of water. The water dissolves the sugar-dextrin and the photoxylin sheet floats off into the water. Each sheet of this sort may then be treated as a single section. Just before immersion in the water it is well to number the photoxylin sheet with some quickly drying oil paint. This method of serial sectioning of tissues embedded in celloidin is the best one I know of when the Weigert-Pal staining is to be employed. Weigert's celloidin method is also a very useful method, and Obregia's procedure is really only a modification of this.

Serial sectioning of tissues embedded in paraffin is a very simple matter, especially if the Minot or Blake-Minot microtome be used. It is possible with these microtomes to make serial sections of small pieces of tissue as thin as 1 μ or less. In order that the series may be satisfactory the temperature of the room and of the knife must be very accurately adjusted, so that they shall be of the proper temperature to suit the paraffin in which the tissue is embedded. In very cold weather and in very hot weather this is not always easy. When the conditions are perfect, however, each section lies flat and smooth, and the sections one after another hold together at their edges in the form of a delicate ribbon. The problem of transferring the ribbon to the slide and of fastening the sections upon the slide so that when the paraffin is removed no particle of tissue may be lost or displaced, has been variously solved. Three principal methods are employed: (1) Schallibaum's collodion; (2) Mayer's albumen, and (3) the water or alcohol method.

In 1883 Schallibaum recommended mixing one part of collodion with three or four parts of oil of cloves or oil of lavender. The mixture, which makes a clear solution, is spread thinly over the surface of a glass slide by means of a camel's-hair brush. Sections are placed upon the surface and gently warmed over a water bath for from five to ten minutes until the oil has evaporated. The sections adhere firmly and can be passed through almost any fluid without being removed. Absolute alcohol, or equal parts of alcohol and ether, will dissolve out the collodion, and hence in these fluids sections may be lost if they are left in them for a long time. The method is of especial advantage when tissues have been stained in bulk, but is not quite safe when the staining is to be done upon a slide.

Mayer's albumen is made as follows: 50 c.c. of glycerin is mixed with the same quantity of fresh egg albumen. To the mixture 1 gm. of sodium salicylate is added. The whole is well shaken and filtered into a clean bottle. Instead of salicylate of soda some other preservative, like carbolic acid or thymol, may be employed. The mixture is spread in a thin layer with a camel's-hair brush on the surface of the slide, each section being well pressed down upon the albumen with the brush. The sections are then warmed for a few minutes on a water bath, kept just above the melting point of the paraffin. As soon as the paraffin has melted the slide is put into xylol, which dissolves out all the paraffin, and then placed in absolute alcohol, after which it is passed through graded alcohols to water, and is then ready for staining. Care should be taken not to have too thick a layer of albumen, otherwise as it coagulates a slight opacity occurs which may interfere with the study of the finest structures in the cytoplasm or nucleus.

Most of the disadvantages of the above two methods are avoidable if the water or alcohol method be employed. In this method water or alcohol is placed upon a perfectly clean glass slide, the sections are arranged on it with the aid of a brush which has also been moistened with alcohol, the slide then warmed up to about 40° C. (never up to the melting point of the paraffin); the alcohol or water is allowed to evaporate slowly, best in the thermostat kept at about 37° C. for twenty-four hours, after which the slides may be raised in temperature to the melting point of the paraffin, transferred to xylol to remove the paraffin, thence to alcohol to remove the xylol, and afterward passed through graded alcohols to water, when the staining may be undertaken. The warm alcohol or water spreads the sections evenly, removing any creases which may have been present in the section when it came from the knife. Care must be taken not to have too thick a layer of water or alcohol, or it will be found difficult to keep the sections in their proper order and position on the slide. The water or alcohol will not spread uniformly over the slide unless every particle of grease has been removed from the slide. Sections after hardening in most of the fluids employed in histological technique generally adhere very firmly to the slide by this method. An exception to this statement, however, has to be made with regard to tissues which have been fixed in solutions which contain chrome salts. Those tissues which have been hardened in Müller's fluid or in Flemming's solution do not adhere well, and it is useless to try to employ the method in such cases. One great advantage of the alcohol or water procedure is the absence of any precipitate or opacity due to foreign substances.

When the block of tissue to be cut in paraffin is large it is best not to try to make ribbons of the sections, but to remove each single section from the knife and put it in its proper place on the slide.

Flatau, of Berlin, has recently described a method by means of which serial longitudinal sections through the whole spinal cord can be prepared. It is especially applicable when it is desired to use the method of Marchi for the study of recent secondary degenerations. The spinal cord of the animal which has been submitted to experiment is removed whole about fifteen or twenty days after the operation. A weight is attached to the cauda equina in order to avoid twistings or distortions of the cord. Two threads are drawn through the dura mater of the upper part of the cord, and the whole spinal cord suspended in a glass jar 3 or 4 cm. broad and about 40 cm. long filled with Müller's fluid. The threads are drawn out of the mouth of the glass jar so that they are held in place by the cork when this is put in. Twenty-four hours later the dura mater is cut open along the ventral and dorsal surface and the Müller's fluid is renewed. The cord remains in this fluid for from two to three weeks, after which it is taken out and hung by means of the threads on a stand where it swings free in the air. It is then split lengthwise through the ventral longitudinal sulcus and the dorsal longitudinal septum by means of a Graefe's cataract knife, in order that Marchi's fluid may better penetrate the tissue. The splitting is not carried as far as the lowest part of the conus medullaris. The spinal cord thus retains its connection in its lower part, and the two halves can later be very easily applied to each other. The spinal cord is next hung in a tall glass jar filled with Marchi's fluid and kept in a warm place. Flatau recommends gradual increase in the strength of the osmic acid of the solution with frequent changing of the fluid. He leaves the tissue in the Marchi's fluid for from three to five weeks, after which the cord is washed for twenty-four hours in running water, dehydrated in alcohol, and embedded in celloidin. The tissue is then placed upon a specially prepared block of wood and fastened in Becker's microtome. The sections are cut of a thickness varying from 60 to 80 μ, are dehydrated in alcohol, cleared in carbol xylol, and mounted in balsam on long glass slides.

STAINING METHODS.

These may be divided into: (1) those used for staining masses of tissue in bulk, and (2) those used for the staining of sections.

Staining in Bulk.—This method is particularly applicable to the staining of the whole nervous system, for example, of embryos or of small animals where serial sections are to be made. For ordinary purposes, perhaps no better stain is available than the alum cochineal of Czokor or Partsch. Powdered cochineal is boiled for a long time in a five-per-cent. solution of alum. After filtration some preservative like salicylic acid is added to prevent the growth of moulds or bacteria. Herrick recommends sulphate of aluminum instead of alum.

Alum cochineal stains very well after nearly all kinds of fixation and hardening. According to the size of the mass of tissue to be stained it is left in the alum cochineal for from one to four days; then washed out thoroughly in water and passed very gradually through graded alcohols, embedded in paraffin, after which serial sections may be made. Grenacher's alum carmine may also be used if desired. Beale's ammonia carmine and Grenacher's borax carmine are also much employed for staining in bulk. If desired tissues may also be stained in bulk by one of the various hæmatoxylins which have been introduced. The formula of Boehmer and that of Delafield are especially to be recommended (*vide infra*).

Golgi's method and Ehrlich's method may be considered as methods for staining in bulk. They will be described further on.

Staining of Sections.—For the staining of sections very different methods have been employed, some being suitable for the demonstration of one element, others for the demonstration of other elements in the tissue. Every attempt has been made by neurologists to devise elective staining methods suitable for the demonstration of the various constituents in the nervous organs. Sections may be stained upon the slide after fixation thereon, or they may be first stained and afterward transferred to the slide.

It will be convenient to divide the staining methods as follows: A. Methods which give information concerning the external form of the nerve units or neurones. B. Methods which demonstrate the internal morphology of the neurones. C. Methods which demonstrate especially the myeline sheaths. D. Methods especially devised for the demonstration of axones or axis-cylinder processes. E. Methods especially applicable to neuroglia. F. Methods for demonstrating certain fibrillary and reticular structures.

A. METHODS WHICH GIVE INFORMATION CONCERNING THE EXTERNAL FORM OF THE NERVE UNITS OR NEURONES.—The method above all others which has been of service in recent years in demonstrating the external morphology of the nerve cells and their processes is that introduced by Golgi and the various modifications which his method has undergone in the hands of other investigators.

The slow method is carried out as follows: The fresh, small pieces not over 1 to 1.5 cm. large are immersed in a large quantity of a two-per-cent. solution of bichromate of potash, where they remain for a month in summer or two months or more in winter, the strength of the solution being gradually increased to five per cent. The pieces are then placed in a 0.75 solution of silver nitrate, where they remain for from twenty-four to forty-eight hours, after which sections are cut.

The second method of Golgi is sometimes known as the mixed method; small pieces of tissue remain for three or four days in bichromate of potash solution, after which they are transferred to a mixture of two parts of a one-per-cent. acid solution and eight parts of a two-per-cent. bichromate of potash solution. Here they remain for from three to eight days, after which they are passed through a silver bath as by the other method.

The rapid method of Golgi, which is the one so much used by Ramón y Cajal, is carried out as follows: Very small pieces of tissue are placed directly in a mixture of one part of one-per-cent. osmic acid solution and four parts of a three-and-one-half-per-cent. solution of bichromate of potash. In this fluid they remain for a few days, after which they are passed through the 0.75-per-cent. solution of silver nitrate. The impregnation of the nervous elements varies according to the length of time the tissues are immersed in the first solution. Thus in the human spinal cord, neuroglia is best stained by an immersion of from two to three days; the cell bodies of neurones by an immersion of from three to five days; axones and collaterals by an immersion of from five to seven days.

The so-called double method gives very good results with some tissues; the bits of tissue after having been passed through the procedure above described are subjected at once to a repetition of the process, after which the sections are cut.

Cox's modification of Golgi's method is very valuable when it is desirable to impregnate a large number of elements in the tissue. He proceeds as follows: Bits of fresh tissue are immersed for from two to three months in the following fluid: bichromate of potash (five-per-cent solution), 20 parts; bichloride of mercury (five-per-cent. solution), 20 parts; distilled water, 30–40 parts; chromate of potash with strong alkaline reaction (five per-cent. solution), 16 parts. The bits of tissue are then washed for half an hour in ninety-per-cent. alcohol to remove the excess of sublimate, after which sections are cut and mounted by Golgi's method. The sections can be counterstained, if desired, with carmine or hæmatoxylin.

Ehrlich's Vital Staining with Methylene Blue.—This method, introduced by Ehrlich in 1886, has been of very great importance, inasmuch as it is an elective stain for nerve elements in fresh tissues. Ehrlich injected a solution of methylene blue dissolved in salt solution into the vessels of animals, and found that the axis cylinders of many of the nerve fibres as well as numerous nerve endings stained after a time when the animal was killed and the tissues exposed to the air. While the nerve elements stain of a deep blue color, the other structures in the tissue remain but little or not at all affected. The staining was transient. S. Meyer recommends subcutaneous injection of the methylene blue, using 2 c.c. of a saturated solution beneath the skin every fifteen minutes until the animal dies. A method of fixation was introduced by Dogiel. This investigator laid the pieces of tissue after staining in an aqueous solution of ammonium picrate. A much better fixing method is that of Bethe, who proceeds as follows: the tissue at the acme of staining is immersed in the following mixture: ammonium molybdate, 1 gm.; distilled water, 10 c.c.; hydrogen peroxide, 1 c.c.; pure hydrochloric acid, 1 drop. The fluid must be well cooled before the stained tissues are immersed in it, after which they remain immersed for from two to five hours in the ice box. They are then removed from the refrigerator, left at the room temperature for a few hours, washed for thirty minutes in distilled water, dehydrated quickly in cool alcohol, cleared in xylol, embedded in paraffin, and finally, after sectioning, mounted in balsam. Alum cochineal may be used as a contrast stain. Neuroglia does not stain by Ehrlich's method. A slight modification has been introduced by Ramón y Cajal in order to demonstrate the gemmules or lateral buds on the dendrites of the primary cells in the brain. He uses a saturated solution of Grübler's methylene blue by covering thin pieces of the fresh brain with the fluid by means of a small brush. The fluid is allowed to act for three-quarters of an hour, after which the tissues are washed in salt solution and fixed in the following modification of Bethe's fluid: ammonium molybdate, 1 gm.; distilled water, 10 c.c.; pure hydrochloric acid, 1 drop. After fixation for from two to three hours the excess of ammonium molybdate is removed by washing in water. The tissues are then hardened for from three to four hours in a forty-per-cent. solution of formol to every one hundred parts of which five parts of a one-per-cent. solution of platinum chloride have been added. The formol is washed out by passing it through an alcoholic platinum chloride solution, after which the tissues are embedded in paraffin; thick sections are made. They are passed through absolute alcohol to which platinum chloride has been added, cleared in xylol, and mounted in balsam.

Other methods which stain the nerve-cell protoplasm deeply, leaving the fibres almost unstained, are of value for demonstrating the external form of the nerve cells. These all, however, illustrate also the internal morphology of the nerve cells, and the methods will accordingly be described under the next heading.

B. Methods Which Demonstrate the Internal Morphology of the Neurones.—The methods to be considered here are those which bring out especially well the nuclear and cytoplasmic structures. Generally speaking, it may be said that basic dyes stain the chromatic part of the nucleus, and certain substances (*e.g.*, the Nissl bodies or tigroid masses) in the cytoplasm, while acid dyes stain the other cytoplasmic structures and some of the so-called achromatic substances in the nucleus. It is not unusual in staining methods to employ combinations of the two procedures. Thus, in the much-used hæmatoxylin and eosin stainings, the hæmatoxylin differentiates the chromatic part of the nucleus, while the eosin stains more particularly the protoplasm. Again, when methylene blue and erythrosin are employed, the methylene blue stains the nucleoli, the chromatin of the nuclei, the tigroid bodies, and the neurosomes of the protoplasm, while the erythrosin stains the meshwork-like structure which is visible in the cell protoplasm as well as certain constituents of the nucleus. Sometimes structures are present in the cells or nuclei which take up both kinds of dye and assume a color intermediate between them. The most common stains perhaps are the carmine and cochineal stains, hæmatoxylin and its derivatives, and various aniline dyes.

Carmine and Cochineal Stains.—These have already been referred to above. Alum carmine, alum cochineal, and borax carmine are important stains, and are all applicable to tissues which have been hardened in formalin or in Müller's fluid. A large part of the older work on the nervous system was carried out with the aid of such stains. Various picrocarmines have been used, but in the writer's experience they possess no distinct advantages and can well be omitted from ordinary technique. Carmine is of no value for demonstrating the finer structures in the nerve-cell protoplasm or in the nerve-cell nucleus. It is, however, generally useful when simply the gross relations of the white and gray matter need to be studied.

The Hæmatoxylin Stains.—Hæmatoxylin is an exquisite nuclear stain and differentiates the structures in the nuclei far better than does any of the carmine stains. Tissues left long in hæmatoxylin solutions are usually overstained, and it is accordingly desirable to differentiate, after staining, with some decolorizing agent like acid alcohol. The two best solutions of hæmatoxylin for ordinary work are those of Boehmer and Delafield.

Boehmer's hæmatoxylin is made as follows: two solutions are kept ready: (*a*) a ten-per-cent. solution of hæmatoxylin in absolute alcohol; (*b*) a one-per-cent. solution of alum. A few days before it is desired to use the stain one adds enough of the first solution to the second to make the color a bright violet. The fluid is then exposed to the light for a few days, by means of which it is turned much darker. Sections can be stained in the fluid for from two to five minutes, after which they are quickly differentiated in one-per-cent. solution of hydrochloric acid in seventy-per-cent. alcohol. They are then thoroughly washed out in water and allowed to remain in the water until they turn blue (fifteen minutes); they can then be dehydrated (after previous counterstaining, if desired), cleared in creosote or oil of origanum, and mounted in balsam. The nuclei are stained of a deep blue violet color, while the protoplasm retains only a light blue tinge.

Delafield's hæmatoxylin is made as follows: 2 gm. of hæmatoxylin are dissolved in 10 c.c. of absolute alcohol. This solution is mixed with 200 c.c. of an ammonia-alum solution. The mixture is exposed to the light in an uncorked vessel for four or five days, after which it is filtered; 100 c.c. of alcohol and the same quantity of glycerin are then added. The fluid is again filtered and the bottle corked. It is then permitted to stand for a long time, at least six weeks, generally several months, in order to ripen. It is then ready for use. It is employed in much the same way as Boehmer's hæmatoxylin.

Ehrlich's acid hæmatoxylin has been much recommended, but possesses no especial advantages over the two formulæ given above. It is stated, however, that it stains more quickly and that the staining is more permanent.

The iron hæmatoxylin stains are very valuable as nuclear dyes and for the demonstration of particular elements of the cytoplasm, especially the centrosomes. The method of Heidenhain or that of Benda may be employed. According to Heidenhain, sections hardened in sublimate are immersed for from half an hour to three hours in a one-and-one-half to four per-cent. solution of ferric alum (clear violet crystals). After washing with water the sections are stained for thirty minutes in an aqueous 0.5-per-cent. solution of hæmatoxylin. They are then quickly washed in water, immersed again in a solution of ferric alum, which removes a part of the stain, the differentiation being followed under the low power of the microscope. After the differentiation has been completed the preparations are washed for fifteen minutes in running water, dehydrated, cleared, and mounted in balsam. The method is applicable to sublimate or alcohol material, but gives less good results with tissues hardened in chrome salts. It is best in using it to make sure that the sections are thin. They should not be thicker than 5 μ. A contrast stain may be used if desired.

Benda's method also gives very good results and is applicable to tissues fixed in all of the ordinary reagents. Sections are immersed for twenty-four hours in the liquor sulfurici oxydati of the German Pharmacopœia, diluted with one or two volumes of water. After thorough washing, first with distilled water and afterward with water from the tap, the sections are stained in a one-per-cent. aqueous solution of hæmatoxylin until they turn of a deep black color. After rinsing in water they are then differentiated in a thirty-per-cent. aqueous solution of acetic acid, the decolorizing process being carefully controlled by means of the low power of the microscope. The method is very valuable for the study of the central nervous system and the peripheral nerves. Acid fuchsin or eosin may be used with advantage as a contrast stain. Mayer's hæmalum may be used instead of the ordinary hæmatoxylin solutions. The particular application of hæmatëin, by Apáthy, for the demonstration of special elements will be referred to further on.

Weigert's hæmatoxylin method for demonstrating karyokinetic figures is as follows: tissues which have been hardened in ninety-six-per-cent. alcohol are cut into very thin sections and placed in tinctura ferri Rademacheri for thirty minutes. They are then washed quickly in water and stained for half an hour in a fluid of the following formula: hæmatoxylin, 1; absolute alcohol, 10; distilled water, 100. The sections are washed in water, differentiated in feeble acid alcohol, after which they are allowed to remain in ordinary tap water for ten minutes. They are dehydrated in absolute alcohol, cleared in xylol or some essential oil, and mounted in balsam.

The Aniline Stains.—Of the aniline dyes the most useful in histological work are methylene blue, gentian violet, thionin, and toluidin blue. Aniline blue black, and saffranin have also been employed. The triple stain of Biondi-Ehrlich, which consists of a mixture of methylene green, acid fuchsin, and orange G, is of advantage for the differentiation of some elements, but is especially difficult to apply successfully to the staining of tissues. Saffranin is particularly valuable as a nuclear stain, especially in the study of karyokinesis. Methylene blue is most employed in the study of the nervous system for the staining of the nerve cells according to the method of Nissl or some modification of this method. Thionin may, if desired, be used in its place. Toluidin blue also appears to yield equally good results.

Nissl's Method of Staining with Methylene Blue.—Nerve tissues as fresh as possible are hardened in ninety-six-per-cent. alcohol for three days. After the hardening has been completed small blocks of tissue are fastened to cork by Weigert's method with gum arabic without embedding. The sections are cut in the ordinary microtome, placed in ninety-six-per-cent. alcohol, and stained in a watch glass of the dye. The dye has the following constitution: methylene blue B. pat., 3.75; Venetian soap, 1.75; distilled water, 100. A watch glass full of this dye containing the sections is heated over a spirit flame until small bubbles arise, making a crackling noise. The temperature corresponds to about 65° or 70° C. The sections are then transferred to a differentiating fluid which has the following composition: colorless aniline oil, 10 parts; ninety-six-per-cent. alcohol, 90 parts. The aniline oil must not only be colorless at first but must be kept carefully protected from the light. The process of differentiation of the sections is considered complete when no more coarse clouds of color go off into the fluid.

The differentiated sections are placed upon glass slides, carefully dried with filter paper, cleared in oil of cajeput, and again dried with filter paper.

The slide is then flooded with benzin, after which benzin colophonium is placed over the sections, and the whole slide is heated until all the benzin gas has been driven off. Should the material catch fire no harm will be done provided the flame is blown out immediately.

To make the benzin colophonium, one adds benzin to pure white rosin and allows the mass to stand for twenty-four hours. A fluid, transparent substance should be obtained which is ready for use. If it is too thin it may be allowed to evaporate until of the correct consistency; if too thick, more benzin may be added.

With this method the tigroid masses in the cytoplasm are exquisitely demonstrated. The method is especially valuable for the pathology as well as for the anatomy of the nerve cell.

Held's Modification of Nissl's Method.—This investigator, after hardening in alcohol, sublimate, Van Gehuchten's fluid, or other fluids, embeds small blocks of tissue in paraffin and cuts sections of a thickness varying from 1 to 10 μ. For the finest histological details sections of 1 μ or less are sometimes valuable, but for general pathological studies thicker sections are of much greater service. A thickness of from 15 to 30 μ is by no means too great for most purposes.

The paraffin sections are fastened upon the slide by the alcohol method (*vide supra*).

The sections, after they have been fastened to the slide, are first stained in the following solution: erythrosin, 1; distilled water, 150; acetic acid, 2 drops. This stain is permitted to act for a minute or two, and may be slightly warmed. Sections are then washed in water, after which they are stained in methylene blue. Held's staining fluid consists of equal parts of the methylene-blue solutions used by Nissl (*vide supra*) and a five-per-cent. aqueous solution of acetone. The sections are heated in this staining fluid and the heating is continued until all smell of acetone disappears. The sections remain in the fluid while it cools, after which they are differentiated in a one-tenth of one-per-cent. solution of ordinary alum. The process of differentiation requires from a few seconds to several minutes, according to the nature and thickness of the section. When the differentiation is complete sections are quickly washed in water, dehydrated as quickly as possible in absolute alcohol, passed through xylol for clearing, and then mounted in benzin colophonium according to the method advised by Nissl.

The Nissl bodies are stained of a deep blue color, sometimes showing a slight violet tint. The ground substance of the protoplasm stains red, as do the nuclear membrane and certain other structures in the nucleus. The nucleolus itself stains blue, the neurosomes stain violet, as do also the accessory nucleoli.

Mann's Method of Staining with Eosin and Toluidin Blue.—The sections are fixed in sublimate solution, sectioned in paraffin, fastened upon the slide, treated with iodine to remove the sublimate, and then washed for two minutes in water. The sections which are still somewhat yellow are then placed for from five to ten minutes in a one-per-cent. aqueous solution of eosin. They are then washed in ordinary water, after which they are stained in one-half-per-cent. aqueous solution of toluidin blue for from twenty to thirty minutes. The sections are then quickly washed off in distilled water to remove the excess of toluidin blue, quickly dehydrated in absolute alcohol, during which blue clouds of color go off.

The sections are cleared in xylol and mounted in turpentine balsam. The tigroid bodies and the chromatin of the nucleus and nucleolus stain of a dark blue color; while fibrillary and interfibrillary structures stain red. The method is very safe and reliable.

Harris's Method of Staining with Toluidin Blue.—The tissues are hardened in mercuric chloride, stained in carbolic-acid-water solution of toluidin blue for several minutes, differentiated in alcohol, cleared, and mounted in balsam. If desired, benzo-purpurin may be used as a contrast stain.

Method of Staining with Thionin.—Sections hardened in alcohol or sublimate or formalin are embedded in paraffin and fixed to the slide in the ordinary way. The staining is carried out with a concentrated aqueous solution of thionin, the dye being allowed to act for from three to five minutes. The sections are quickly washed in water and are then differentiated in a ten-per-cent. solution of aniline oil in absolute alcohol. They are cleared in oil of cajeput, then passed through xylol and mounted in xylol balsam.

Gram's Method of Staining, with Gentian Violet, Tissues Which have been Hardened in Alcohol.—Sections are cut in celloidin or paraffin. They are then stained in Ehrlich's solution of gentian violet, which consists of: gentian violet, 1; alcohol, 15; aniline oil, 3; water, 80. The sections are transferred, after staining, to a slide, spread out flat, and treated with the following solution: iodine, 1; iodide of potassium, 2; water, 300. They are then dehydrated in absolute alcohol, cleared in xylol, and mounted in xylol balsam.

Weigert's Fibrin Stain with Gentian Violet.—Sections from tissue hardened in alcohol are stained in Ehrlich's aniline gentian violet (*vide supra*). They are then placed on a slide and blotted with filter paper covered with Lugol's solution. After this has been allowed to act for from fifteen to thirty seconds the sections are blotted again. They are then dehydrated and cleared in a mixture of two parts of aniline oil with one part of xylol. This treatment is followed by pure xylol, in which the sections are washed until all the aniline oil has been removed. They are then mounted in xylol balsam. The method is of particular advantage in pathological histology.

Method of Staining with Aniline Blue Black.—Sections are stained for from thirty to sixty minutes in the following solution: aniline blue black, 0.25; distilled water, 100. The sections are then washed in water, dehydrated in alcohol, cleared in creosote, and mounted in balsam.

The Method of Staining with Saffranin.—Sections of tissue fixed in Flemming's solution are stained in a concentrated aqueous solution of saffranin for from twelve to twenty-four hours. They are then carefully differentiated in absolute alcohol, or, if necessary, in weak acid alcohol. The sections are cleared in oil of cloves and mounted in balsam. With proper differentiation karyokinetic figures are intensely stained, while resting nuclei retain only a feeble pink tint.

Rosin's Method of Staining with the Triple Stain of Biondi-Ehrlich.—Sections which have been hardened in alcohol and embedded in celloidin are treated as follows: They are stained for one minute in the following solution: one part of one-half-per-cent. solution of acid fuchsin is added to four parts of a solution of the following constitution: dry triple stain (Grübler), 0.4; distilled water, 100; 0.5 per cent. acid fuchsin solution, 7 (if the sections are not embedded in celloidin they can be stained for five minutes in the latter solution alone).

After staining, the sections are quickly washed in distilled water which is changed once, the washing requiring from one to two minutes; they are then treated for ten seconds with a feeble aqueous solution of acetic acid (one drop of glacial acetic acid in 100 c.c. of distilled water); they are then again washed in distilled water for sixty seconds to remove all trace of acetic acid. Differentiation is carried out with the aid of absolute alcohol for from two to three minutes, during which clouds of violet color are given off. The sections are cleared in xylol and mounted in balsam. The method requires considerable practice before good results are obtained.

C. METHODS WHICH DEMONSTRATE ESPECIALLY THE MYELINE SHEATHS.—*Method of Exner.*—Pieces of perfectly fresh tissue not more than 1 cm. broad and 0.5 cm. thick are placed in a one-per-cent. solution of osmic acid. There must be at least ten times as much osmic-acid solution as there is tissue by volume. After two days the osmic acid is changed. The tissue can be examined between the fifth and the ninth day. It is washed in water, dried on the surface with filter paper, fastened to cork by means of sealing wax, and then sectioned in the microtome. The sections are placed in glycerin, whence they are brought upon a glass slide and treated with a drop of weak solution of ammonia (20 drops of liquor ammonii caustici in 50 c.c. of water). The myeline sheaths of the nerve fibres are stained black; all other structures remain pale.

Weigert's Method of Staining Myeline Sheaths.—Tissues are hardened in Müller's fluid or in formol followed by Müller's fluid, or in Orth's fluid or in formol followed by four days in the following solution: Potassium bichromate, 5 parts; chrome alum, 2 parts; dilute water, 100 parts. The blocks of tissue are transferred without washing into alcohol and are embedded in celloidin. The sections are placed for twenty-four hours in a saturated solution of acetate of copper diluted with an equal volume of water. They are stained for from twenty minutes to twenty-four hours in the following solution: hæmatoxylin, 1; absolute alcohol, 10; lithium carbonate, 1; distilled water to make up 100 parts. The sections are next washed in water and differentiated in the following solution: borax, 2; ferricyanide of potash, 2.5; distilled water, 100. The sections are then thoroughly washed in water, dehydrated in alcohol, cleared in xylol or carbol xylol, and mounted in balsam. The myeline sheaths of medullated nerve fibres are stained bluish black, the background being of a brownish-yellow color.

Weigert's Rapid Myeline Stain.—Small blocks of tissue are placed for from four to five days in ten-per-cent. solution of formol (four-per-cent. solution of formaldehyde); after this they are placed in a mordant of the following formula: bichromate of potash, 5 parts; chrome alum, 2 parts; boiling water, 100 parts. If desired the hardening and mordanting can be done together by adding 10 gm. of the ten-per-cent. solution of formol to 100 parts of the mordant. If desired, instead of the above treatment Weigert's copper mordant (used for his neuroglia stain) may be employed. This consists of five-per-cent. copper acetate, five-per-cent. acetic acid, and two-and-one-half-per-cent. chrome alum dissolved in water. It has the advantage of making no precipitates on the tissues, and, further, does away with the necessity of treating the sections with copper acetate after they have been cut. If left longer than eight days in the fluid the tissues become very brittle.

Pal's Modification of Weigert's Stain for Myeline Sheaths.—The tissues are prepared as for Weigert's method, except that the sections are not treated with acetate of copper. Sections are stained in Weigert's hæmatoxylin solution for from twenty-four to forty-eight hours in the cold; they are then washed in lithiated water (four per cent.); after washing they are placed in a freshly prepared 0.33-per-cent. solution of potassium permanganate for from twenty to thirty seconds, or until the gray matter looks yellowish. The sections are transferred immediately to the following solution: oxalic acid, 1; potassium sulphite, 1; distilled water, 200. The differentiation is watched closely to see that it does not go too far. Should it not proceed rapidly enough the sections are put back into the solution of potassium permanganate and again exposed to the oxalic-acid solution. When the differentiation has gone far enough the sections are washed out in water, and transferred to a strong solution of lithium for five or ten minutes until they turn of an intense blue color. They are finally thoroughly washed in water, dehydrated in alcohol, cleared in xylol or carbol xylol, and mounted in balsam.

Schaefer's Modification of Weigert's Method.—The treatment is the same as for Weigert's method, except that the sections after having been passed through water are left in Marchi's fluid for some hours; they are then thoroughly washed and stained in the following solution: hæmatoxylin, 1; absolute alcohol, 10; two-per-cent. solution of acetic acid, 100. After they have remained in this fluid for twenty-four hours the sections are washed in water and decolorized according to Pal's method (*vide supra*).

Vassale's Modification of Weigert's Method.—Sections are prepared as in the method of Weigert. They are then stained in a one-per-cent. aqueous solution of hæmatoxylin for from three to five minutes, after which they are washed in water, exposed for a few minutes to the action of a saturated solution of neutral acetate of copper. They are then washed in water and differentiated by Weigert's ferricyanide solution. They are again washed in water, dehydrated in alcohol, cleared in carbol xylol, and mounted in balsam.

Berkley's Modification of Weigert's Stain.—Pieces of tissue 2 mm. in thickness are hardened in Flemming's solution for from twenty-four to thirty hours. They are transferred directly to absolute alcohol which is changed twice on the following day. As soon as the consistency will permit of the making of very thin sections the pieces of tissue are embedded in celloidin and cut under ninety-five per cent. alcohol. After quick washing in water they are laid in a saturated solution of acetate of copper and heated on a water bath for from twenty to thirty minutes, at a temperature of from 100° to 110° F. The fluid is allowed to cool, after which the sections are quickly washed in water and then stained in the following fluid freshly prepared: to 50 c.c. of boiled distilled water are added 2 c.c. of saturated solution of lithium carbonate. The boiling is continued for another minute, after which 1.5 or 2 c.c. of a ten-per-cent. solution of hæmatoxylin in absolute alcohol is added little by little with constant stirring. As soon as cool the fluid is ready for use. Sections placed in the stain are warmed on a water bath to a temperature of 100° F. for from fifteen to twenty minutes or longer. After cooling they are twice washed in water, then differentiated in Weigert's borax ferricyanide solution diluted with one-half or one-third its volume of water. Usually five or six minutes suffice to complete the decolorization. The sections are washed in two waters, dehydrated in alcohol, cleared in oil of bergamot, and mounted in balsam.

Herrick's Modifications of Weigert's Stain for Comparative Work.—For the formulæ used by Herrick his original article is referred to ("Report upon a Series of Experiments with the Weigert's Methods—with Special Reference for Use in Lower Brain Morphology." The State Hospitals' Bulletin, Utica, vol. ii., 1897, pp. 431–461).

Marchi's Method of Staining Degenerated Myeline Sheaths.—Small pieces of tissue are hardened for eight days in Müller's fluid, transferred without washing to Marchi's fluid, which consists of two parts Müller's fluid mixed with one part of a one-per-cent. solution of osmic acid. In the latter fluid the bits of tissue remain for from five to ten days, after which they are washed for twenty-four hours in running water, hardened in alcohol, embedded in celloidin, and cut in the microtome. The sections are cleared in xylol and mounted in xylol balsam. Chloroform balsam is to be avoided. Degenerated myeline sheaths stain of an intense black, while all others remain of a light yellow color or of a slightly grayish tint. The method demonstrates of course only myeline sheaths in the process of degeneration. If degeneration has existed for over three months and the myelin has been absorbed the degenerated fibres are not demonstrable by Marchi's method. The method has proved to be of especial value in experimental work. It is also of great value in studying recent degenerations in human cases in which fresh autopsies can be obtained.

The tissues may be fixed, if desired, in formol before treatment with Marchi's fluid, but the results are not quite so satisfactory as when the original procedure is employed. Formol tissues have the advantage that they warp less than those prepared by the original method.

Vassale's Modification of Marchi's Method.—Instead of two parts of Müller's fluid to one part of the one-per-cent. osmic-acid solution, Vassale uses three parts, and, further, to 100 c.c. of the Marchi fluid thus prepared he adds twenty drops of pure nitric acid. He asserts that by this method precipitates are less abundant and the degenerated fibres stand out much more sharply from the other tissues.

Hamilton's Modification of Marchi's Method.—According to this method Marchi's fluid is applied after the sections are made. The sections are placed in a fluid obtained by macerating brains hardened in bichromate, in chromic-acid solution, and filtering. This bath, he asserts, renders the sections susceptible to the osmium reaction when they are afterward treated with Marchi's fluid. The method requires further testing. The writer's experience with it has not been satisfactory.

D. Methods for the Especial Demonstration of Axones or Axis-Cylinder Processes.—Golgi's method and the method of vital staining of Ehrlich are the best we have for the demonstration of the external form of axones. For the examination of the finer internal structure of axones, various methods have been recommended.

Van Gieson's Method.—Tissues hardened in Müller's fluid are sectioned after embedding in celloidin. The sections are stained for from three to five minutes in Delafield's hæmatoxylin, thoroughly washed in water, and afterward stained in a mixture of saturated picric-acid solution with saturated solution of acid fuchsin. They are then washed quickly in water, dehydrated in alcohol, cleared in oil of origanum, and mounted in balsam. The axis cylinders stain deep red in the acid fuchsin, the myeline sheaths take a yellow tint from the picric acid; all nuclei stain in hæmatoxylin, while neuroglia tissue takes the acid fuchsin, especially in sclerotic areas.

Stroebe's Method for Axis Cylinders.—Tissues hardened in Müller's fluid are sectioned after embedding in celloidin. The sections are stained in a saturated aqueous solution of aniline blue until they are of a deep blue-back color. The staining requires from fifteen to sixty minutes. The sections are then washed in water, differentiated in absolute alcohol to which has been added a few drops of a one-per-cent. solution of caustic potash dissolved in absolute alcohol and filtered after standing twenty-four hours. The sections remain in this fluid until they are of a light brownish-red color, which usually appears after a very few minutes. They are then washed in water, in which the sections turn light blue. As a contrast stain a dilute solution of saffranin is allowed to act for from fifteen to thirty minutes. Sections are dehydrated in absolute alcohol, cleared in xylol, and mounted in balsam. Axones stain deep blue, myeline sheaths orange red, glia fibres blue. The method requires some practice before good results can be obtained.

Held's Method for Studying Axones.—No better mode perhaps of studying the finer internal structure of axones has been devised than Held's modification of Nissl's methylene-blue staining (*vide supra*). The sections must be very thin. The neurosomes and fibrillary or honeycomb structures are exquisitely brought out by this procedure. For showing the neurosomes alone in all parts of the neurones, perhaps the best method is another introduced by Held. The tissues are fixed in a solution of neutral chromate of potash, sectioned in paraffin, and stained with iron hæmatoxylin.

E. Methods Especially Applicable to Neuroglia.—*Weigert's Neuroglia Stain.*—This stain, the method for which was published in 1895 by Carl Weigert of Frankfort, is carried out as follows: Tissues are fixed and mordanted for eight days in the following solution: acetate of copper, 5; acetic acid, 5; chrome alum, 2.5; formol, 10; distilled water, 100. The chrome alum must be dissolved in boiling water, while the acetate of copper and acetic acid are added afterward. If these directions are not followed a precipitate will be formed.

In particular, Weigert advises boiling the chrome alum and water in an enamelled saucepan; when the boiling is active after the chrome alum has been dissolved the flame is turned out and the acetic acid and finely powdered neutral acetate of copper are added. One stirs vigorously until one can feel with the glass rod that the copper salt has almost entirely dissolved. The fluid is then allowed to cool and will remain clear. Tissues which have been hardened for four days in formalin can be placed in this fluid and left for four or five days at the temperature of the thermostat or for eight days at the room temperature. It is perhaps better, however, to harden directly in a fluid to which ten-per-cent. formol has been added. The fluid should be changed on the second day. Weigert states that tissues never become brittle in this fluid. When desired to make sections the pieces of tissue are washed with water, dehydrated in alcohol, and embedded in celloidin. The sections are next placed in some reducing fluid. Weigert recommends a mixture of five-per-cent. chromogen and five-per-cent. formic acid (specific gravity, 1.20) in water. This mixture is filtered carefully, and before it is used one adds to 90 c.c. of the fluid 10 c.c. of a ten-per-cent. solution of ordinary sodium sulphite (that used in photography). The sections are placed first for ten minutes in a 0.33-per-cent. solution of permanganate of potash. They are then washed in water, after which the water is removed and the reducing fluid above mentioned is poured upon the sections. After a few minutes the sections which were turned brown by the permanganate of potash become decolorized. Weigert recommends that the sections be left for from two to four hours in the chromogen mixture.

After removal from the reducing fluid and washing twice in water the sections are placed in a simple saturated aqueous solution of chromogen (made by dissolving five parts of chromogen in one hundred parts of distilled water and filtering).

The sections remain in this solution over night. The longer they stay in this fluid the more stained are the nervous elements of the tissue. They are washed twice in water, after which the sections are ready for the stain. If they cannot be stained at once the sections should be preserved in the following mixture: eighty-per-cent. alcohol, 90 c.c.; five-per-cent. solution of oxalic acid, 10 c.c.

The sections are stained in a methyl-violet solution prepared in the following way: methyl violet in excess is added to hot seventy-per-cent. alcohol, and after cooling the fluid is poured off from the undissolved methyl violet. To every 100 c.c. of this solution are added 5 c.c. of a five-per-cent. aqueous solution of oxalic acid. The sections are placed upon a glass slide, treated with a solution of iodine and iodide of potash (as in Weigert's fibrin stain), after which they are differentiated in a mixture of equal parts by volume of aniline oil and xylol. They are then washed in xylol very carefully several times. Otherwise the preparations do not keep well. They are then mounted in balsam, exposed for from two to five days to diffuse daylight, and afterward kept in cabinets in the ordinary way.

An excellent staining method for neuroglia is that introduced by F. B. Mallory,[*] of Boston. The tissues are fixed in equal parts of a saturated aqueous solution of picric acid and a five-per-cent. solution of formalin. They remain in this for from four to seven days. The tissues are then transferred to a two-per-cent. solution of ammonium bichromate, where they remain for from one to two weeks. They are then washed in water, dehydrated in alcohol, and embedded in celloidin. The celloidin is removed from the sections, which are then stained feebly in carmine and afterward stained by Weigert's fibrin stain.

F. METHODS FOR DEMONSTRATING FIBRILLAR AND RETICULAR STRUCTURES IN THE NERVOUS SYSTEM.—S. Apáthy, of Klausenburg, has introduced several methods which are of the greatest value for staining the neurofibrils in lower animals. . They do not stain, however, the same fibrils in vertebrates. Three principal methods have been introduced by Apáthy.

(1) *Staining of Fresh Tissue with Methylene Blue.*—This method is described in the *Zeitschr. f. wissensch. Mikr.*, Bd. ix., 1892.

(2) *Staining of Hardened Tissue with a Solution of Hæmatëin.*—The tissues may be fixed by any one of several methods: sublimate, sublimate alcohol, corrosive acetic, picric acid, Zenker's fluid, etc. After fixation the tissues may be kept in ninety-per-cent. alcohol until it is desired to stain them. The pieces should not exceed 5 mm. in thickness. They are stained in bulk in a solution of hæmatëin, prepared by successively pouring together equal volumes of the three following ingredients: one per-cent. hæmatëin tincture, concentrated glycerin, and nine-per-cent. alum solution with addition of salicylic acid and acetic acid. The hæmatëin solution is prepared from hæmatoxylin by ripening it. A one-per-cent. solution of hæmatoxylin crystals in a seventy-per-cent. solution of pure alcohol is first made. This is allowed to stand in a flask of good glass which is not quite full. The oxidation of the hæmatoxylin to hæmatëin should go on at the room temperature for from six to eight weeks. The alum solution is prepared as follows: 9 parts of alum, 3 parts of glacial acetic acid, and 0.1 part of salicylic acid are dissolved in 100 parts of water.

The tissue remains in the dye for at least forty-eight hours. It is then washed for twenty-four hours in pure double distilled water, which must be often changed. The tissue is then placed in feebly alkaline water for from three to five hours, after which it is returned for two hours (at most) to distilled water. It is then quickly dehydrated in alcohol and embedded in either celloidin or paraffin.

(3) *Staining of Fresh and Fixed Tissues by the Gold Method.*—The tissue is cut into thin pieces and placed in a solution of yellow gold chloride. The amount of fluid should be ten times the volume of the object. After the treatment with the gold solution the tissue is exposed to the light in a one-per-cent. solution of formic acid (crystallized, specific gravity, 1.223) in distilled water. The tissue should be exposed to direct or indirect sunlight from all sides, the vessel containing it sitting upon a mirror. The exposure to light should not be too short, but exposure for more than twenty-four hours is not advisable. At least six or eight hours is always needed. For full particulars regarding the methods, Apáthy's[*] article is referred to.

Bethe has recently introduced a method by which the neurofibrils in the tissues of human beings and other mammals can be stained; it is as follows: Fresh tissue in discs 4 to 10 mm. thick are laid upon filter paper and immersed in nitric acid of a strength of from three to seven and one-half per cent., where they remain for twenty-four hours, the pieces being frequently turned. They are then transferred to ninety-six-per-cent. alcohol, where they remain for from twelve to twenty-four hours. The pieces are then immersed for from twelve to twenty-four hours in the following mixture: ammonia (specific gravity, 0.95 to 0.96), 1 part; water, 3 parts; ninety-six-per-cent. alcohol, 8 parts. The temperature should not exceed 20° C. The pieces are then transferred for from six to twelve hours to ordinary alcohol. After this they are placed in acid alcohol of the following constitution: hydrochloric acid, concentrated, 1 part; water, 3 parts; ninety-six-per-cent. alcohol, 8–12 parts. In this the tissues become light yellow or nearly white if they have only been feebly acted upon by the nitric acid. After treatment with acid alcohol the tissues are again placed in ordinary alcohol for from ten to twenty-four hours. They are then washed in water for from two to six hours. After this they are molybdanized. The blocks of tissue are transferred to a four-per-cent. solution of ammonium molybdate, where they remain for twenty-four hours. They are then quickly washed in distilled water, dehydrated in ninety-six-per-cent. alcohol for from ten to twenty-four hours, then in absolute alcohol for the same length of time; cleared in xylol or toluol and embedded in paraffin (not in celloidin).

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[*] Mallory, F. B.: Ueber gewisse eigenthümliche Färbereactionen der Neuroglia. Centralbl. f. allg. Pathol. u. path. Anat., Jena, Bd. vi., 1895, October 31st, S. 753–758.

[*] Apáthy, S.: Das leitende Element des Nervensystems und seine topographischen Beziehungen zu den Zellen. I. Mittheilung, Mittheil. d. Zool. Station Neapel, Bd. xii., p. 495–748.

The neurofibrils and the Golgi network can be stained by this method.

For further details and for a modification of the method, Bethe's original article is referred to.*

Microscopic Appearances.

The brains of different animals vary, of course, in size and complexity. The present article deals almost entirely with the minute anatomy of the human brain.

In human beings we designate as brain or encephalon that portion of the central nervous system enclosed within the skull. It is continuous at the level of the great occipital foramen with the spinal cord or medulla spinalis. The brain, like the spinal cord, is enclosed in membranes known as meninges: (1) A firm tough membrane (dura mater encephali); (2) a very delicate membrane closely crowded with minute blood-vessels and closely attached to the surface of the brain substance (pia mater encephali); and (3) a membrane between the two former membranes, (arachnoidea encephali).

The gross anatomy of the brain is described in another article in this Handbook.

With the naked eye it is seen that the main mass of the brain consists of a very white substance, the so-called white matter, or *substantia alba*, and a gray substance, the so-called gray matter, or *substantia grisea*. The substantia alba is more abundant than the substantia grisea. In general it may be said that in the brain the gray substance is chiefly on the surface of the organ and in certain large gray masses, the so called basal ganglia· while the white matter is situated internally, being surrounded by the gray. The relative positions of white and gray matter are, in the brain, exactly the reverse of those in the spinal cord, where the gray matter is inside and the white matter outside. In the region of the brain nearest to the spinal cord, a very irregular arrangement of gray and white matter is met with, the various masses of gray matter being known as "nuclei" of the gray substance. These nuclei include among other structures the nuclei of origin and termination of various cerebral nerves.

Histological research has shown that the nervous system, like the other tissues of the body, consists of an aggregation of cells and intercellular substances derived from cells. All the cells of the central nervous system except those of the meninges and the blood-vessels, with the tissue immediately adjacent to the latter, are believed to be derived from the ectoderm or outermost layer of the embryo.

The cells in the brain may be divided into two main groups: (1) the true nerve cells or *neurones*, and (2) all other cells including those of the *neuroglia* and *ependyma*.

The *nerve cells*, or *neurones*, differ markedly from other cells in the body in that portions of the protoplasm are drawn out in many instances to form threads of great length. Nowhere in the body do cell processes so long, so complex, so much branched, and so delicate occur as in the nervous system. While nerve cells vary distinctly in size, shape, and mode of branching, the most common type possesses the following characteristics: each nerve cell or neurone consists of a *cell body* or *perikaryon*, a number of protoplasmic processes or *dendrites*, and a single long, delicate process which often becomes surrounded with an especial fatty sheath (myelin), the so-called *axone* or axis-cylinder process.

The nerve cells, compared with other cells of the body, are as a rule, large, contain large nuclei, poor in chromatin, and usually provided with a large nucleolus.

The *dendrites* or protoplasmic processes are thick at their origin and gradually diminish in calibre as they pass from the cell, owing to manifold subdivision. Through the multiplication of these processes the area of the surface of the protoplasm of the cell is enormously increased.

The *axone* differs from the dendrite in that it arises by a thin wedge of origin, usually from the cell body, but sometimes from one of the dendrites near the origin of the latter. The axone has a smooth, regular surface and very even calibre, even when followed for a long distance from the cell body which gives it origin. The length of the axone may vary greatly. If it is very long it usually

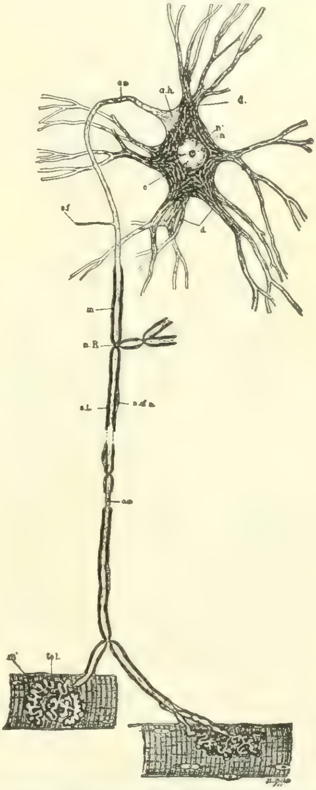

Fig. 905. Schematic Representation of a Lower Motor Neurone. The motor cell from the ventral horn of the spinal cord, together with all its protoplasmic processes and their divisions, its axis-cylinder process with its divisions, side fibrils, or collaterals, and end ramifications (telodendrions or motor end-plates) in the muscle, represent parts of a single cell or *neurone*. *a.h*, Axone hillock devoid of Nissl bodies, and showing a tendency to fibrillation; *a.c*, axis cylinder or axone, also indistinctly fibrillated. This process, at a short distance from the cell body, becomes surrounded by a myeline sheath, *m*, and a cellular sheath, the neurilemma, the latter not being an integral part of the neurone; *c*, cytoplasm showing the dark-colored Nissl bodies and lighter ground substance; *d*, protoplasmic processes (dendrites) containing Nissl bodies; *n*, nucleus; *n'*, nucleolus; *n.R*, node of Ranvier; *sf*, side fibril; *n of n*, nucleus of neurilemma sheath; *tel.*, motor end-plate or telodendrion; *m'*, striped muscle fibre; *s.L.*, segmentation of Lantermann. (From "The Nervous System and Its Constituent Neurones," D. Appleton & Co., New York, 1899.)

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* Bethe, A.: Das Molybdanverfahren zur Darstellung der Neurofibrillen und Golginetze im Centralnervensystem. Zeitschr. f. wissensch. Mikr., Bd. xvii., 1900, S. 13–35.

becomes surrounded by a myeline sheath (*inaxone*, Golgi's cell type I.) (Fig. 905); if it is very short, terminating near the cell body, it does not become surrounded by a myeline sheath (*dendraxone*, Golgi's cell type II.) (Fig. 906). Many axones, especially the longer ones, give off as they pass through the nervous tissue delicate lateral branches known as *collaterals*. These collaterals are also surrounded by fatty sheaths. A few lateral branches given off very close to the origin of the axone do not become surrounded by fatty sheaths inasmuch as this portion of the axone is also free from investing sheath. These non-medullated lateral branches are known as the *side fibrils* of Golgi. All collaterals and the terminals of the axones themselves ultimately become exhausted by manifold subdivision in regions where these fine subdivisions can enter into relations with the cell bodies or branches of the cell bodies of other nerve cells or neurones. These ultimate branchings with formations of delicate terminal arborizations are the so-called *telodendrions*. It is believed that it is the great mass of nerve cells or neurones which are responsible for the truly nervous functions, namely, the reflex, instinctive, and volitional activities of the body.

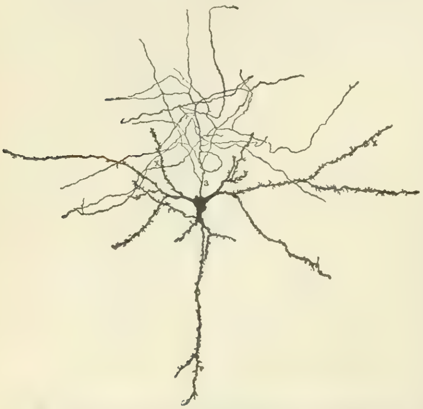

FIG. 906.—Golgi's Cell of Type II. or Dendraxone from the Cerebrum of a Cat. (After Kölliker.) The coarse protoplasmic processes, *x*, are easily distinguishable from the axis-cylinder process, *a*, though the latter soon loses its identity, exhausting itself by multiple division at a short distance from the cell.

The *ependymal cells* are those which line the central canal of the central nervous system. Thus, they line the walls of the ventricles of the brain, those of the aqueduct of the cerebrum and the central canal of the spinal cord.

The *neuroglia cells*, also ectodermal in origin, are widely distributed throughout the nervous tissues of the brain and are believed by most observers to represent supporting cells. They include the spider cells, the stellate glia cells, and various other forms of cells. They are present in both the white and the gray substance.

The *intercellular substances* in the brain have only begun to be worked out; while many believe that the only intercellular substances present are the fluids of the lymph derived from the blood, others maintain the existence of an enormous number of fibrils between the cells. Studies of Weigert indicate the existence of neuroglia fibrils differentiated from the neuroglia cells. Many of these fibrils pass directly through the bodies of the glia cells. The studies of Apáthy and Bethe indicate the presence of highly differentiated fibrils inside the bodies of the true nerve cells or neurones. These fibrils they believe pass from one neurone to another. Nissl has gone even further and asserts that great masses of these fibrils exist outside the cells, and he believes that the peculiar character of the gray matter, especially of that of the cerebral cortex, is due to the presence of these fibrils between the cells. The views of Nissl have not as yet been confirmed.

The gray and white matter of the brain are richly supplied with blood by means of a very indirect network of capillaries derived from the intracranial blood-vessels. The supply of blood to the gray substance is much more copious than that to the white substance.

After these preliminary statements the cells and intercellular substances of which the brain is composed may be considered more in detail.

The *nerve cells* or *neurones* will be considered first. A striking feature is the uniformity in type met with in various parts of the brain. There are, however, differences even in external form which are easily recognizable by the trained histologist. The cells in certain of the gray masses have so distinct a type that their origin can be predicted at once when they are seen under the microscope. The differential features lie in the form and size of the cell body, the characters of the dendrites and axones, and the relations of these to the cell body.

Among the *cell bodies* or *perikaryons* there are great variations in size. Thus, for instance, the large cells of Betz in the paracentral lobule possess cell bodies many times the size of the minute perikaryons of the olfactory granules. The shape, too, of the cell bodies varies much. The pyramidal cell of the cortex of the cerebrum, the flask-shaped cell of Purkinje in the cerebellar cortex, and the large multipolar ganglion cells of Deiters' nucleus may be recalled.

The *dendrites* of the nerve cells are usually numerous, rarely single. These processes appear to be much drawn-out portions of the cell body. The relation of the processes to the cell body varies with different types of neurones. Thus, in the nuclei of origin of the motor cerebral nerves, large dendrites project from nearly all portions of the surface of the cell body. From the cells in the hippocampus, dendrites project only from the two poles of the cell. In the cerebellar cortex the neck of the flask-shaped cell is a huge dendrite which subdivides

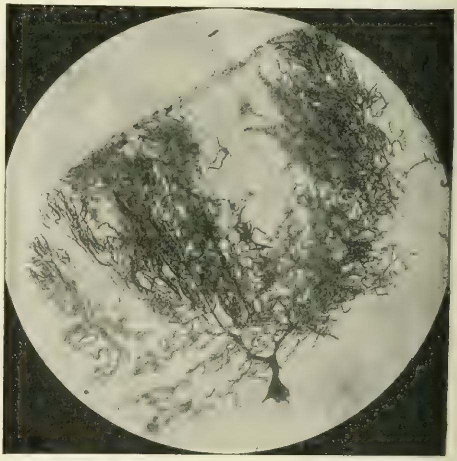

FIG. 907.—Photomicrograph of a Normal Purkinje Cell from the Human Cerebellar Cortex. (After Berkley.)

soon into two or more large branches, which then go on to subdivide over and over again until a forest of dendritic branches has been formed which has no equal elsewhere in the nervous system (Fig. 907). In the cerebral cortex the pyramidal cells give off dendrites from the apex and from the lateral angles of the pyramid (Fig. 908). While in some of the neurones the various dendrites are approximately equal in size and in extent of distribution (cells of motor nuclei), in other neurones the size and mode of distribution of fibres from a given cell may be very different. Thus, taking a pyramidal cell of the cerebral cortex again for an example, while the apical dendrite forms a large, strong, straight branch which as a rule extends a long distance from the cell before breaking up into an end tuft of subdivisions, the smaller dendrites given off from the angles of the pyramid are of much smaller calibre, are often tortuous, branch quickly after leaving the cell body, and soon exhaust themselves by multiple subdivision in an area close to the perikaryon. The branches of the individual dendrites, no matter how far away from the cell they terminate, appear to end free. It was believed that they always came into direct contact or even into more intimate connection with the walls of blood-vessels, but this view has been given up. It has been proven, however, that they come into intimate relation with the terminals of the axones and collaterals of other neurones, and it is believed by many that this relation is one which subserves the purpose of a transference of impulses, that is to say, the relation is thought to be a conduction relation. The surface of the dendrites is by no means smooth, and in this particular is in strong contrast with the surface of the axones. In well-impregnated Golgi preparations and in certain methylene blue preparations it is possible to make out minute projections from the surface of certain of the dendrites, especially from the apical dendrites of the pyramidal cells in the cerebral cortex. These prickle-like projections, when seen under very high powers, have a nodular extremity. They are the so-called lateral buds or gemmules (Fig. 909). In the course of a dendrite definite bulgings are sometimes met with. These bulgings or varicosities are at times found in what are believed to be normal tissues, but appear to be more frequent in the brains of individuals dead of certain pathological processes. In normal individuals these varicosities or bulgings are probably to be regarded as artefacts (Fig. 910). Their pathological significance in abnormal brains is difficult to determine. A few nerve cells

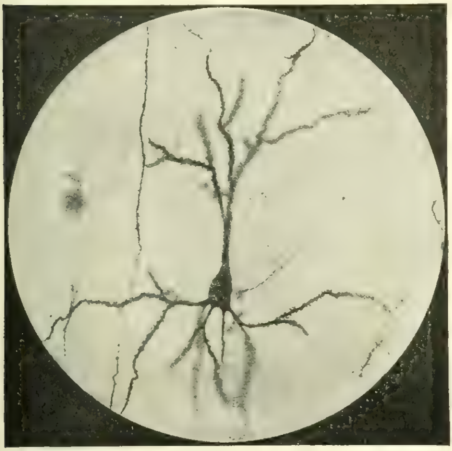

FIG. 908.—Photomicrograph of a Normal Pyramidal Cell from the Cerebral Cortex of the Guinea-Pig. (After Berkley.) The single-branched apical dendrite and the basal dendrites show distinctly the lateral buds or "gemmules." The axone is relatively smooth.

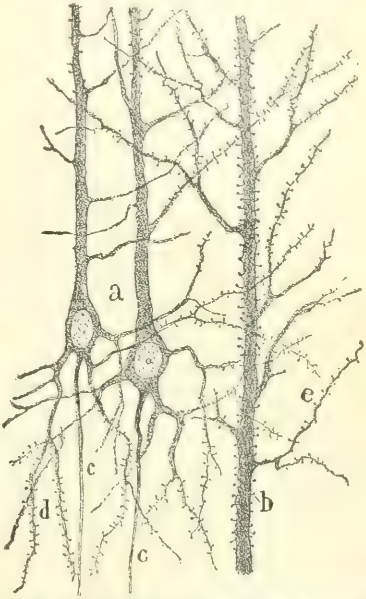

FIG. 909. The Lateral Buds or Gemmules on the Apical Dendrites of the Pyramidal Cells of the Cerebral Cortex. Methylene-blue preparation. (After Ramón y Cajal, S., "Textura del sistema nerviosa," p. 55, Fig. 13.)

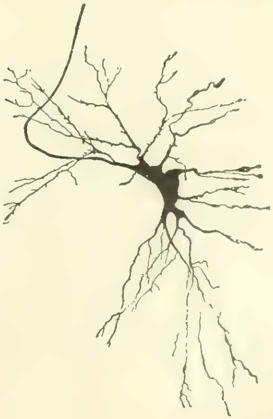

FIG. 910.—Multipolar Nerve Cell from the Cord of the Embryo Calf, Showing Varicosities of the Dendrites. (After Van Gehuchten.)

have been described in which no dendritic processes could be made out. They are the so-called adendritic neurones.

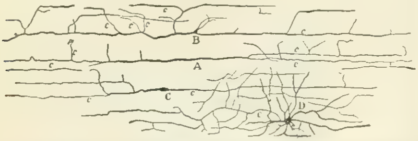

FIG. 911.—Special Cells (Polyaxones) of Molecular Layer of Cerebral Cortex of a Dog One Day Old. (After Ramón y Cajal.) *A*, Fusiform cell; *B*, triangular cell; *C*, another fusiform cell; *D*, polygonal cell with numerous dendrites and an axone which divides repeatedly; *c*, axones.

The *axone*, as has been stated, is usually single. There are neurones, however, which possess two axones, the so-called *diaxones*. In the cerebral cortex are found certain cells which possess several processes which must be regarded as axones. They are known as *polyaxones* (Fig. 911). An axone which in its course divides or bifurcates into nearly equal parts is known as a *schizaxone*. A few neurones devoid of axones have been designated as *anaxones* or *amacrine cells*.

The *telodendrions* of axones come into relation with the cell bodies and dendrites of other neurones. This relation is very intimate, as will be described farther on, and is believed by many to be a conduction relation for the transference of impulses. Inasmuch as the telodendrion of the axone of one neurone usually comes into such relation with the cell bodies and dendrites of a number of other neurones, it seems likely that there is under such conditions a multiplication of elements in the direction of the conducting path. This anatomical relation is the basis of the "avalanche conduction" hypothesized by Ramón y Cajal (Fig. 912). Certain special forms of telodendrion are met with in different parts of the brain. Of these the calyx-like terminals in the nucleus of the trapezoid body and the climbing fibres of the cerebellar cortex (Fig. 913) may be mentioned. The term *synapsis* has been introduced to designate the anatomical relation of one neurone with another.

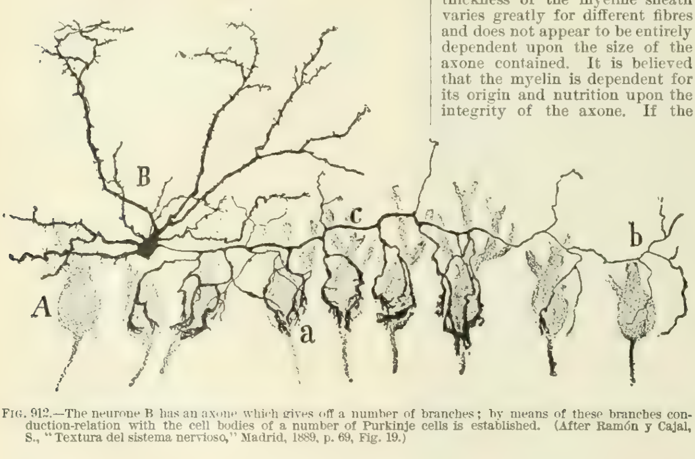

FIG. 912.—The neurone B has an axone which gives off a number of branches; by means of these branches conduction-relation with the cell bodies of a number of Purkinje cells is established. (After Ramón y Cajal, S., "Textura del sistema nervioso," Madrid, 1889, p. 69, Fig. 19.)

It has been mentioned that the dendraxones have short axones without an investment, while the inaxones possess long axones provided with a myeline sheath. In the central nervous system these long axones do not, however, possess any sheath which corresponds to the neurilemma of the peripheral nerves.

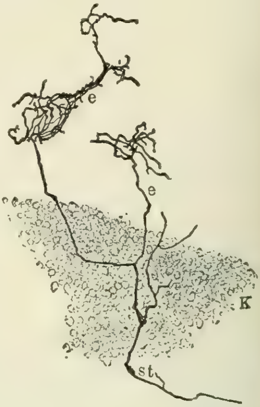

FIG. 913.—The So-Called "Climbing Fibres" of the Cerebellar Cortex from the Brain of a Child a Month and a Half Old. (After Kölliker.)

The *myeline sheath* of the axones is strongly refractive and glistening. Examined fresh it is quite homogeneous, but soon undergoes certain alterations. One of the most marked of these is the appearance of certain oblique splits in the medullary substances which divide the myelin into a number of segments, known as Lantermann's segments. Treatment of the myeline sheath with hot ether or alcohol dissolves out a large portion of the myelin, but leaves behind a delicate network which is very resistant (Fig. 914). This network is not digestible in artificial pancreatic juice. It is the so-called neurokeratin of Ewald and Kühne, and is believed to be allied chemically to the keratin of the epidermis.

The myeline sheath at certain intervals shows definite indentations, the nodes of Ranvier. The thickness of the myeline sheath varies greatly for different fibres and does not appear to be entirely dependent upon the size of the axone contained. It is believed that the myelin is dependent for its origin and nutrition upon the integrity of the axone. If the axone be cut through, the myeline sheath as well as the axone distal from the point of section undergoes complete degeneration and is absorbed usually in about three months.

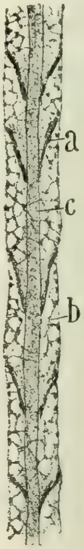

FIG. 914.—Nerve Fibre After Treatment with Ether. (After Ramón y Cajal, S., "Textura del sistema nervioso," Madrid, 1899, p. 200, Fig. 62.)

The medullated collaterals possess the same structure and undergo the same mode of temination as do fine axones. The non-medullated side fibrils behave like the non-medullated axones of dendraxones. Some of the non-medullated side fibrils, however, have the peculiarity of running back to end in the form of flat terminal plates upon the cell body of the neurone to which they belong.

The axone close to the nerve cell is usually entirely devoid of any covering of myelin (Fig. 915). A reticular investment, however, has been demonstrated upon the cell bodies and dendrites by Golgi (Fig. 916). This investment may be homogeneous upon the finer branches of the dendrites. Its exact nature has not yet been determined, but Golgi suggests that it may be of the nature of neurokeratin. These fine networks are drawn, as it were, like stockings over the perikaryon and dendrites. Golgi's network does not seem to be identical with the networks of Held and Bethe. Held's networks (Fig. 917) are believed to be formed by the subdivisions of fine terminal axones. The nature of Bethe's pericellular network (Fig. 918) is not yet clear.

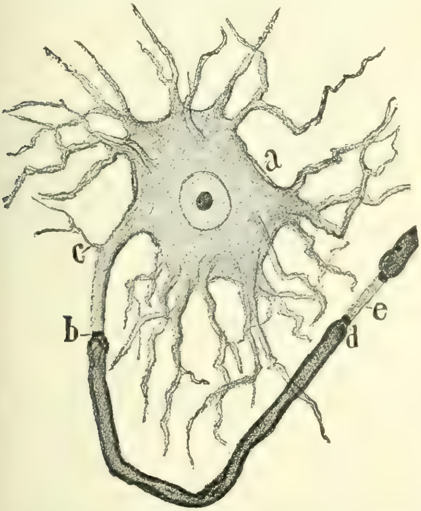

FIG. 915.—Methylene-Blue Preparation. The axone close to the perikaryon is devoid of myeline sheath. (After Ramón y Cajal, "Textura del sistema nervioso," Madrid, 1899, p. 113, Fig. 34.)

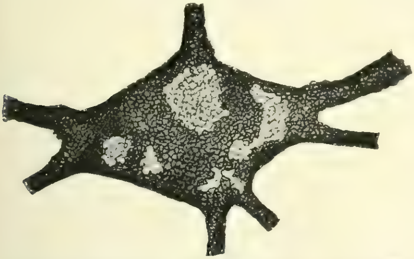

FIG. 916.—Nerve Cell Showing Reticular Investment. (After C. Golgi, *Arch. Ital. di Biol.*, Turin, t. xxx., 1898, p. 62.) The cell is from the ventral horn of the spinal cord of a cat.

We may pass now to a consideration of the finer structure of the protoplasm and nucleus of the nerve cell or neurone, the observations which have preceded having dealt almost entirely with the external form of the neurone and its various branches. The protoplasm of the cell body and dendrites of the neurone varies consider-

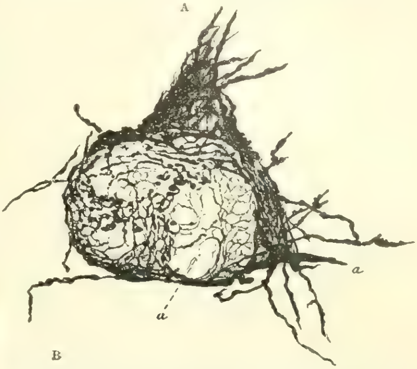

FIG. 917.—Pericellular Networks Believed by Held to be Formed by the Terminals of Axones. Golgi preparations from a cat twenty days old. Sections 70 μ thick. (After H. Held, *Arch. f. Anat. u. Physiol.*, Leipsic, 1897, Anat. Abth., Suppl. Bd., Taf. xiv., Figs. 5, 7, and 8.) A, Cell with network from nucleus nervi cochleæ ventralis. The pericellular network surrounds the whole cell and a dendrite passing upward. The fibre *a* corresponds to one of the thickened fibres of the n. cochleæ described by Ramon y Cajal and Held. Beyond the thickened spot fibrils go to join the general pericellular network.

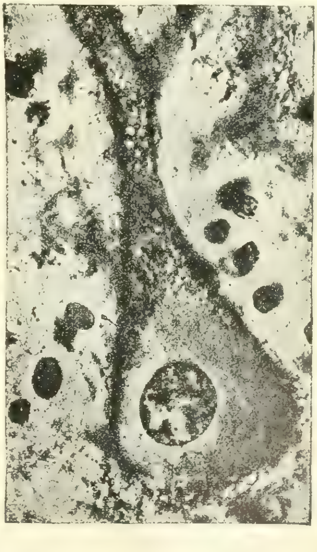

FIG. 918.—Network About Perikaryon and Dendrites Demonstrable by the Method of Bethe. (After F. Nissl, *München. med. Wochenschr.*, Bd. xlv., 1898, S. 1024, Figs. 1, 2.) Nerve cell from the nucleus dentatus of a dog.

ably in appearance from that of the axone, especially in fixed preparations. In entirely fresh specimens taken from an animal just killed, little if any difference can be made out, the protoplasm in all parts of the neurone being homogeneous. The protoplasm of the cell body contains an attraction sphere or archiplasm within which are situated one or more centrosomes. The peripheral portion of the protoplasm or so-called exoplasm differs somewhat in appearance from the central portion of the protoplasm or so-called endoplasm, the former showing a more marked tendency to a fibrillar structure, the latter showing in most preparations a somewhat more granular appearance. The ground substance of both exoplasm and endoplasm looks in ordinary preparations to be more or less homogeneous.

The nucleus of the nerve cell or neurone is always situated in the cell body, never in one of the branches, and as a rule occupies nearly a central position under normal conditions. This nucleus is larger than that of most cells of the body, is very poor in substances which stain in nuclear dyes, the so-called achromatic portion of the nucleus being relatively very abundant. There is nearly always one large, easily stainable nucleolus. Sometimes the nucleoli are multiple.

The appearance of the protoplasm of the neurones varies with different methods of preparation. With certain methods the protoplasm has a spotted appearance owing to the staining of bodies known as *tigroid masses*, or *Nissl bodies* (Fig. 919). By other methods a vacuolar or spongy network can be demonstrated, and in the meshes of the network certain minute staining bodies, the so-called *neurosomes*, appear. By still other methods of preparation a fibrillar structure becomes apparent. Accordingly, very divergent views prevail as to the ultimate nature of the protoplasmic structure, each investigator's views being colored by the method with which he is most familiar and in the results of which he places most confidence. Until further knowledge has been gained it is safer for the neuro-histologist to work with the various methods, describing accurately the results attained with each, and holding his mind open with regard to the ultimate nature of the substance he is working with.

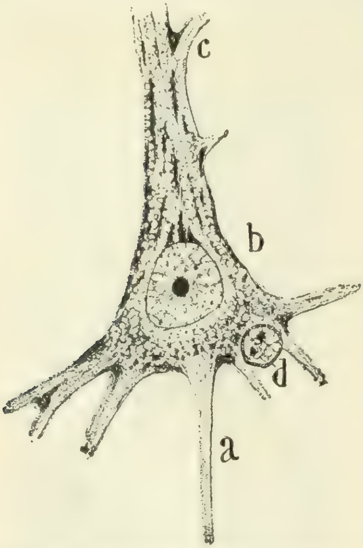

FIG. 919.—Part of a Pyramidal Cell from the Cerebral Cortex Showing the Tigroid Masses. (After Ramón y Cajal, S., "Textura del sistema nervioso," Madrid, 1899, p. 121, Fig. 37.)

In sections stained with Nissl's and similar methods the protoplasm of the neurone is seen to be made up, aside from any pigment which may be present, of two main constituents: one which stains in the basic dye employed, and another which remains unstained in this dye. The former substance is known as the *stainable substance* of Nissl, the latter as the *unstainable substance* of Nissl. The terms chromatic and achromatic have been applied to these two substances, but there are objections to their use.

The stainable substance of Nissl usually occurs in masses of varying size and form. Again, the masses themselves may be arranged in rows, groups, or networks so as to give a characteristic appearance to the cell. Each of the masses in turn may possess a definite structure, but this varies greatly with the mode of fixation which has been employed. Thus a single mass may, with one kind of fixation be made up of very minute granules, with another kind of fixation of very much coarser granules. Vacuole-like appearances in the individual stainable masses are also frequently met with. These stainable bodies in the nerve-cell protoplasm (first seen and described by Flemming) have been subsequently studied by a large number of investigators, and notably by Nissl, who has made the appearance caused by their presence in different nerve cells the basis of an elaborate classification. They are frequently spoken of in neurological articles as Nissl bodies, but it is better to employ the term introduced by von Lenhossék, namely, tigroid bodies or tigroid masses, from the Greek word τιγροειδής, spotted.

The larger tigroid masses tend to assume definite forms with a given method of fixation, and these forms appear to be constant in the same variety of nerve cell from different individuals. Three of the more interesting forms of tigroid bodies are the nuclear caps, the wedges of division, and the tigroid spindles.

Nuclear caps are masses of tigroid, shaped more or less like cones, each cone being hollowed out inside. These cones of tigroid sit usually upon the nucleus of the nerve cell. As a rule, when they are present in the neurone there are two nuclear caps corresponding to two opposite nuclear poles.

The *wedges of division* are masses of stainable substance situated at the point where a dendrite divides into two branches. The base of the wedge is directed away from the body of the nerve cell.

The *tigroid spindles* consist of oblong or spindle-shaped masses of the stainable substance. These spindles, thick in the middle, become thin at the extremities and sometimes run out into long, thread-like forms.

The stainable substance of Nissl is limited to the perikaryon and to the dendrites. It is not found in the axone nor in that portion of the cell body from which the axone is immediately derived. This area of the cell body free from the stainable substance of Nissl is known as the axone hillock.

On the basis of findings in specimens stained by his method Nissl divides all nerve cells into two great groups. In the first group, that of the *somatochrome* nerve cells, he includes the cells in which the cytoplasm surrounds the nucleus completely and exhibits a distinct contour. This group includes: (1) the *arkyochrome* nerve cells; (2) the *stichochrome* nerve cells; (3) the *arkyostichochrome* nerve cells, and (4) the *gryochrome* nerve cells.

By *arkyochrome* nerve cells (Fig. 920) Nissl refers to those in which the stainable substance of the protoplasm is arranged more or less in the form of a network.

The term *stichochrome* is applied to the nerve cells in which the masses of tigroid are arranged in rows or threads which run in a similar direction. The best example of a stichochrome nerve cell is met with in the nerve cells of the nuclei of origin of the spinal and cerebral motor nerves.

By *arkyostichochrome* nerve cell Nissl formerly meant a type of cell in which there was a combination of the arkyochrome arrangement with the stichochrome arrangement. He cited, as an example of this type, the Purkinje cells of the cerebellar cortex. Since making his original classification Nissl has suggested certain alterations, among which is one in which he gives up the term arkyostichochrome, classing cells of that group now among the arkyochrome cells.

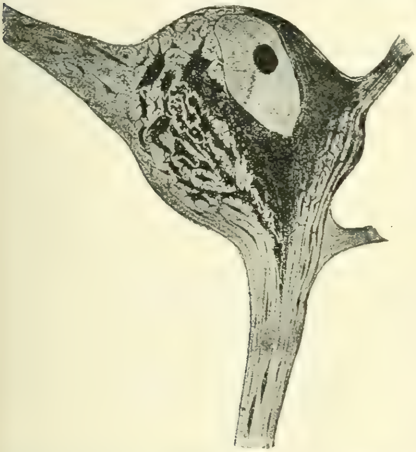

FIG. 920.—Nerve Cell from Olfactory Bulb of Rabbit. (After Nissl.) Somatochrome nerve cell of the arkyochrome variety in the parapyknomorphous condition.

Nerve cells in which the stainable substance is present in the form of minute granules without any very definite arrangement are called *gryochrome* nerve cells by Nissl.

The second great group of nerve cells in Nissl's classification includes all cells not falling in the former group. And Nissl divides the cells of this group into (1) *cytochrome* nerve cells and (2) *karyochrome* nerve cells.

In the *cytochrome* nerve cells only traces of a cell body are to be made out. The nucleus is about the size of that of an ordinary leucocyte. Several varieties of cytochrome cells are distinguished by Nissl.

The *karyochrome* nerve cells also possess only traces of a cell body; but the nucleus is larger than that of the cytochrome nerve cell, being always larger than the nuclei of the neuroglia cells and as a rule of the size of ordinary nerve-cell nuclei.

A further subdivision of the cells of each of the categories above mentioned is based upon the differences in staining which the individual cells show. Thus, cells which are stained extremely deeply are designated by Nissl as *pyknomorphous* cells—that is, cells in which the tigroid masses are very closely arranged in the cell body. On the other hand, cells in which the stainable substance is present in small amounts are designated as *apyknomorphous* cells, the tigroid masses being rather widely separated from one another by the non-stainable substance. The term *parapyknomorphous* has been introduced by Nissl for stages intermediate between the pyknomorphous and the apyknomorphous condition.

Care must be taken in working with Nissl's method not to lay too much stress upon certain appearances in the nerve cells. Now and then in ordinary preparations a single cell or a group of cells will be found to be stained most intensely, as though the stainable substance of Nissl were uniformly distributed through the cell and were present in large quantities. These cells are called by Nissl *chromophile* nerve cells. They are in all probability artefacts due to the mode of fixation of the tissue in which they occur.

In sections of nerve cells stained by Held's method, especially if the sections be cut very thin (0.5 to 1 μ), the tigroid bodies are found to present a finely granular appearance. Each tigroid mass or Nissl body, if studied with an oil-immersion lens, is seen to be made up of a mass of granules often varying in size and sometimes exhibiting a characteristic arrangement. Along with the granules another substance, which Held describes as a coagulum-like mass which stains somewhat differently by his method from the principal granules of the tigroid mass, can be made out. Vacuoles of different sizes occur also in the tigroid bodies. Held is of the opinion that the tigroid bodies do not occur preformed in the nerve cell inasmuch as no indication of their presence can be made out in perfectly fresh nerve cells when examined with the very best optical apparatus. He believes, and I agree with him, that the substances which form the tigroid are precipitated substances. By the use of fixing reagents of different kinds, or even by the use of alcohols of different strength, the constituent granules of a tigroid mass may be precipitated in different ways. Whereas forty-per-cent. alcohol throws down these substances in very fine granules, ninety-six-per-cent. alcohol will precipitate them in much larger granules. The significance of such an observation for pathological histology is obvious, for if one is to draw conclusions with regard to changes in the tigroid masses in disease he should make sure that the pathological tissues he studies shall be compared with normal tissues from exactly the same region, fixed and prepared in precisely the same way.

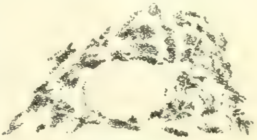

FIG. 921.—Nerve Cell from Deiters' Nucleus in the Rabbit. Section 3 μ thick. The tissue has been exposed to the digestive action of a mixture of pepsin and hydrochloric acid at 40° C. for twelve hours. The ground substance has been dissolved out and the Nissl bodies alone remain. (After Held.)

The tigroid masses are not digestible in artificial stomach juice; whereas the unstainable substance of Nissl quickly digests in this fluid (Fig. 921). On the contrary, weak and strong solutions of the alkalies will dissolve out the tigroid masses, but will leave the unstainable

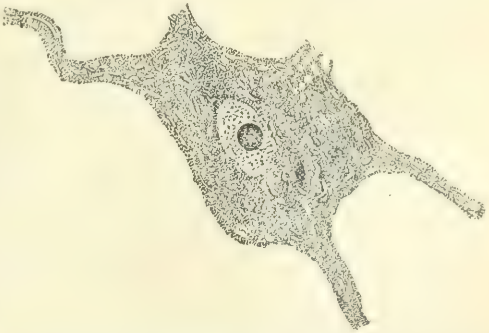

FIG. 922.—Nerve Cell from the Gray Matter of the Lumbar Cord of the Ox. Alcohol fixation. Treatment for four days in concentrated aqueous solution of lithium carbonate. The Nissl bodies have been dissolved out, and the ground substance alone remains. (After Held.)

substance of Nissl practically unaltered (Fig. 922). The chemistry of the tigroid bodies is interesting. The substances of which they are made up has been shown to contain iron and phosphorus. It seems not unlikely that these substances should be grouped among the nucleo-albumins or nucleo-proteids.

As to the unstainable substance of Nissl, very little can be made out if the method of Nissl alone be employed. Stained by his method and mounted in benzin colophonium his unstainable substance shows no structure, or if any but little, and so in such preparations is often described as the colorless, homogeneous ground substance of the nerve cell. Other methods of preparation, however, reveal in this unstainable substance of Nissl very remarkable appearances. Among the methods most suitable for its examination may be mentioned Held's modification of Nissl's method. Very careful studies by this method have been made by Held himself. The ground substance of the nerve-cell protoplasm which corresponds to the unstainable substance of Nissl is stained of a deep red color by this method; while the tigroid bodies or stainable substance of Nissl are stained of a blue color. It is easy to estimate the relative quantities of the two substances present and to make out their reciprocal relations in cells of different types. Thus, for example, the tigroid in the cell bodies of the nuclei of origin of the motor cerebral nerves and the cell bodies of great reflex systems (such, for example, as those of Deiters' nucleus) is found to preponderate, the ground substance in such cells being limited to what looked like narrow beams and bridges between the tigroid masses. On the other hand, the tigroid is relatively scanty in the large cells of Betz in the cerebral cortex, in the huge flask-shaped cells of Purkinje in the cerebellar cortex, and in numerous other cells in the brain. In these cells the amount of ground substance is relatively much greater than that of the tigroid. If the dendrites be followed out into their finer subdivisions one comes always sooner or later to a part of the dendrite where tigroid bodies disappear.

The ultimate branchings of the dendrites, as far as can be made out by Held's method, are devoid of the tigroid substance. These ultimate branches of the dendrites, together with the axones and the axone hillock which are also entirely free from tigroid, form the most suitable places for the study of the ground substance by itself. Held finds in this ground substance longitudinal threads and cross threads which he takes to be sections of honeycomb network, the spaces of which are stretched out lengthwise and arranged in rows; that is to say, Held sees in the ground substance of protoplasm a structure like that postulated by Bütschli for protoplasm in general. He lays emphasis on the fact that very different pictures are obtainable by the use of a variety of fixing reagents. And he believes that the great differences in the deviating views of investigators in general are to be attributed in large part to this fact. Held concludes from his studies that the fibrils which have been described by so many observers in the axis-cylinder processes are nothing more than the sections of the longitudinal walls of the honeycomb structure above mentioned. He has never been able to make out distinctly isolated fibrils running near one another, but in longitudinal sections of the axone or cross sections of the same structure he makes out constantly a network or mesh-work-like structure. The meshes vary in size. In the meshes can be made out granules, sometimes very fine, sometimes somewhat larger, lying most often in the nodal points of the network, or also frequently in its spaces. These granules are arranged so that two or several of them are always contained between one or several of the long oval spaces which vary in length and breadth. The granules are not arranged with perfect regularity, except in this: they are placed in definite rows behind one another parallel to the long axis of the axone. This arrangement in rows is explained from the position of the granules as regards the long-meshed network of the axone. Held designates that part of the protoplasm of the axone which gives the appearance of a meshed structure as the *axospongium*, while the granules just referred to he calls *neurosomes*. While these neurosomes are most easily demonstrable in the axone and axone hillock, they are by no means confined to these structures but are also present in the ground substance of the protoplasm of the cell body and of the dendrites; although in these latter regions they have a different arrangement from that met with in the axone. It will be seen that Held's studies are closely in accord with the investigations of Bütschli, who has always maintained that the fibrils described by other investigators are only apparently fibrils, and that they are everywhere connected by delicate transverse threads which arise from the minute nodular swellings seen on the so-called fibrils. The fact that fixing reagents of different concentration give rise to meshworks of different size makes it seem likely that the honeycomb appearance is due to a vacuolization of the protoplasm caused by the fixing reagents. In thinking of the actual structure of protoplasm, therefore, one must conceive of certain peculiarities of its composition which determine its vacuolization in the way described. But one should not think of these vacuoles or meshes actually existing in the living protoplasm.

The neurosomes described by Held in the axone have nothing in common with the Nissl bodies or tigroid substance, but appear to be identical with the granules observed by various investigators in the axis-cylinder protoplasm. The number and distribution of the neurosomes vary markedly in the same and in different axis cylinders. They stain by Held's method of a violet tint. At the axone hillock the neurosomes are arranged in rows. In the terminals of the axone and in the terminals of collateral branches of the axone the neurosomes are extremely abundant—much more abundant than in any other part of the nerve-cell protoplasm (Fig. 923).

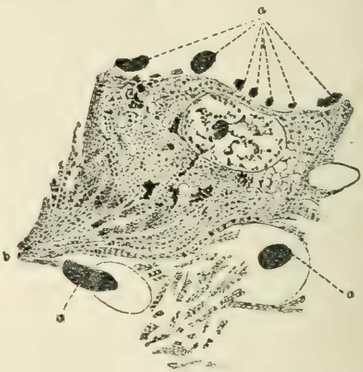

FIG. 923.—Cell of the Nucleus Corporis Trapezoidei of an Adult Rabbit. Fixation with Van Gehuchten's mixture; paraffin section 1.5 μ thick; erythrosin methylene-blue staining. (After H. Held, *Arch. f. Anat. u. Physiol.*, Anat. Abth., Leipsic, 1897, Taf. x., Fig. 3.) The axis cylinders (*a*) which go by the cell are stained homogeneously; the fibres (*b*) terminating in the cell contain large numbers of isolated neurosomes; the lower border of the cell enclosed by the terminal axone shows very distinctly a most intimate union between the axis-cylinder protoplasm and the ground substance of the cell body, since here the same plasma layer is common to both. On the right-hand side the cytospongium is wide-meshed, owing to coarse vacuolization, on account of which the axis-cylinder terminal looks to be more independent from the rest of the cell mass.

The protoplasm of an axis-cylinder process of a neurone is continuous through the axone hillock with the ground substance (unstainable substance of Nissl) of the cell body and dendrites. But in the cell body and dendrites the anatomical appearances are complicated by the presence of the tigroid bodies which are deposited in them in various forms. Held's method shows a very similar structure in the cell body and dendrites to that met with in the axone, as far as the ground substance is concerned. The meshwork in the cell body resembles the axospongium of the axone, but the meshes are somewhat less close and the staining shows some differences. The arrangement of the meshwork is of course also influenced by the deposition of the tigroid masses. Held calls the meshwork in the cell body the cytospongium. The neurosomes in the cell body vary in size, number, and distribution in different nerve cells. In the dendrites neurosomes can be seen in rows placed in such close apposition that they look like beaded rods.

The neurosomes are well seen in specimens fixed in neutral chromate solutions which do not precipitate the tigroid bodies. When sections of such tissues are stained with iron hæmatoxylin the form, number, and distribution of the neurosomes are particularly clear.

Other views of the ultimate structure of the ground substance are held by Flemming, Altmann, Ramón y Cajal, and Dogiel.

Flemming maintains the existence of definite fibrils in the ground substance. He does not, however, deny the possibility that these fibres may form the network.

Altmann, who has directed his attention chiefly to the granules in nerve cells observable by his particular method of staining, speaks of granules and of an intergranular substance. At least a part of Altmann's granules corresponds to the neurosomes of Held; while a large part of Altmann's intergranular substance evidently corresponds to Held's cytospongium and axospongium.

Ramón y Cajal describes the ground substance as consisting of a network with granules situated at the nodal points.

Dogiel, who is an adherent of the fibrillar doctrine, describes very fine fibrils in the ground substance. He finds that the fibrils have a definite and peculiar arrangement, differing in different types of nerve cells. He describes and pictures minute granules in his fibrils. As far as one can tell from a comparison of his illustrations with those of Held, it must be concluded that the granules in Dogiel's fibrils are identical with the rows of neurosomes described and pictured by Held.

Very different appearances from those just described are met with in the protoplasm of the nerve cells if they be stained by the hæmateïn or the gold-chloride method of Apáthy. These methods demonstrate morphological constituents inside the protoplasm which appear to be definite fibrils. In many places the fibrils are independent of one another, but especially in the cell body they anastomose freely, according to Apáthy, to form a neural reticulum.

Apáthy, whose work has been chiefly upon invertebrate animals, divides all cellular elements within the nervous system into two kinds of cells, which he designates "nerve cells" and "ganglion cells" respectively. The "nerve cell" has the power of building neurofibrils

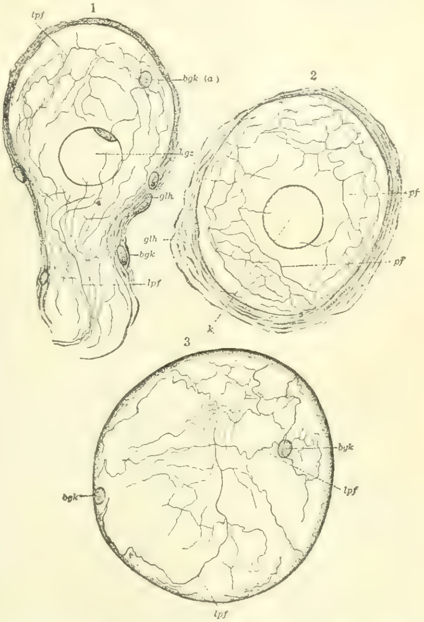

FIG. 925.—Colossal Ganglion Cell (Type *G*) from the Leech. (After S. Apáthy, "Mitth. aus der Zool. St. zu Neapel," Bd. xii., 1897, H. 4, Taf. xxviii., Figs. 4, 5, and 6.)

(1) The neurofibrils of a colossal ganglion cell of a posterior median section, with indication of the external glia sheath and connective-tissue nuclei. *bgh*, Connective-tissue nucleus; *glh*, glia sheath; *kgz*, nucleus of the ganglion cell; *lpf*, "conducting" primitive fibril.

(2) Cross section of a ganglion cell of type *G*, showing plexus of neurofibrils.

(3) Section of a colossal ganglion cell with plexus of neurofibrils. The meridian-like decussation of the neurofibrils at the pole of the cell is illustrated.

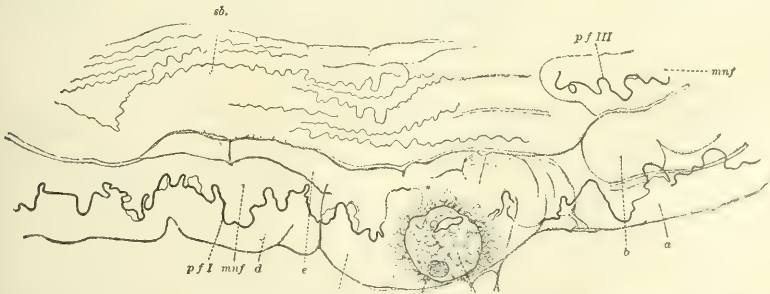

FIG. 924.—Motor-Nerve Spindle in Longitudinal Section of the Right Anterior Nerve Stem from the Leech. (After S. Apáthy, "Mitth. aus der Zool. St. zu Neapel," Bd. xii., 1897, H. 4, Taf. xxiv., Fig. 3.) The somatoplasm of the nerve cell is simply indicated around the cell nucleus, *zkn*. Near this nerve spindle are seen some primitive fibrils in sensory bundles, *sb.*; the contours of the motor-nerve spindle correspond to a focus somewhat above the level of the nucleoli; those branches of the motor nerve-divide, *mnf*, which are visible, are *a*, *b*, *c*, *d*, *e*. *p f I* represents the primitive fibril projected upon the surface of the drawing paper as far as it is contained in the section. The dotted points correspond to the place where it is not contained in the section. The asterisk indicates a division of the primitive fibril into two limbs.

(Fig. 924), while the "ganglion cell" does not possess this power. Neurofibrils built by "nerve cells" can, however, leave the cell in which they arise and pass through one or more ganglion cells and ultimately become connected with a sensory surface or with a muscle fibre. One neurofibril can accordingly pass through a great number of cells, and inasmuch as the different neurofibrils are connected with one another by means of anastomoses, Apáthy conceives of the conducting apparatus in the whole nervous system as a continuum of neurofibrils. A neurofibril varies in calibre in different parts of its course, being largest where it arises. It consists, according to Apáthy, of a complex of "elementary fibrils," and as the neurofibril follows its course through a series of "ganglion cells" it gives off on its way at shorter or longer intervals numerous elementary fibrillæ until finally it itself consists of one elementary fibril. While the neurofibrils pass through ganglion cells which do not give origin to them, Apáthy has put forward the hypothesis that the force which is to be conducted along the neurofibrils arises in the ganglion cell. Two kinds of these ganglion cells are met with in the leech: (*a*) the large ganglion cell and (*b*) the small ganglion cell. The large ganglion cell, Apáthy's type G (Fig. 925), possesses the following characters: each cell has a pear-shaped process by way of which neurofibrils arrive within the protoplasm of the cell. Once inside, the neurofibril breaks up into its elementary fibrils, and these can be seen to diverge like meridians into what Apáthy calls the external chromatic zone of the cell. As these elementary fibrils pass peripheralward they can be seen to form free anastomoses with one another. On the far side of the cell the elementary fibrils turn round and converge again by passing through the body of the cell once more at the pear-shaped process, going out of the cell as another neurofibril. Each pear-shaped process accordingly contains two kinds of neurofibrils, and Apáthy suggests that one of the fibrils carries impulses into the cell and the other carries impulses out of the cell.

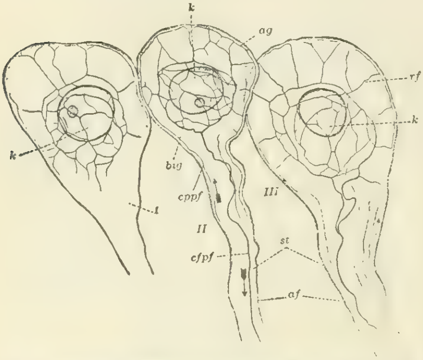

FIG. 926. Three Pear-Shaped Ganglion Cells of Type *K*, in Longitudinal Section from the Leech. (After S. Apáthy, "Mitth. aus der Zool. St. zu Neapel," Bd. xii., 1897, H. 4, Taf. xxviii., Fig. 7.) The internal or perinuclear plexus of neurofibrils is well shown, as are also the radial fibres. The peripheral plexus is indicated. *af*, Axis fibril which Apáthy takes to be motor; *ag*, external intracellular plexus of neurofibrils; *big*, internal perinuclear plexus of neurofibrils; *cfpf*, cellulifugally "conducting" primitive fibril, see *cppf*, cellulipetally "conducting" primitive fibril; *k*, nucleus of the ganglion cell; *rf*, radial fibrils connecting the external plexus with the internal plexus of neurofibrils; *st*, stem process of pear-shaped ganglion.

In Apáthy's second type of "ganglion cell," which he calls the "small ganglion cell" and designates as "type K" (Fig. 926), somewhat different appearances are met with. Each pyriform process contains within it one thick neurofibril, which passes nearly through the centre of the process, and several finer neurofibrils in the periphery of the process. The finer neurofibrils, however, entering the cell body pass out to the periphery of the protoplasm of the cell and break up into a dense reticulum formed by the anastomosis of the "elementary fibrils" of which they are composed. This anastomosis occurs in what Apáthy calls the outer chromatic zone of the cell. Small rami of the fibrils pass from this peripheral plexus inward to reach the internal chromatic zone of the cell, where another rather fine plexus of elementary fibrils is formed. The composing fibrils of this plexus, after having undergone free anastomosis, converge and pass toward the pyriform process, where they unite to give rise to the single large neurofibril, which passes away from the cell through the centre of the pear-shaped process. Apáthy believes that the peripheral finer neurofibrils of the pear-shaped process are sensory and that the single central neurofibril of large calibre is motor.

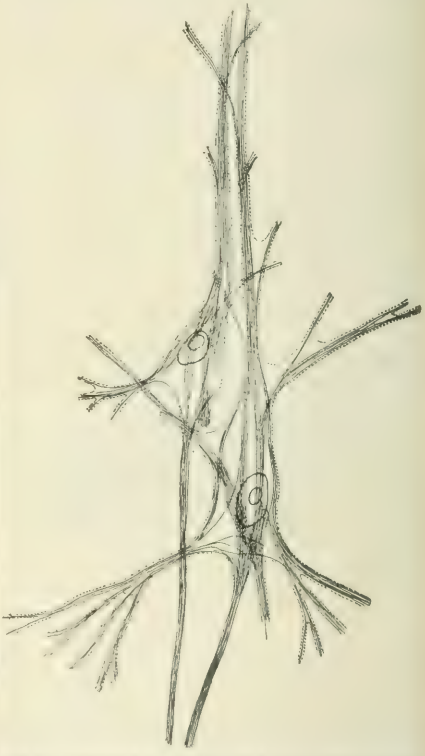

FIG. 927.—Neurofibrils in Pyramidal Cells of the Cerebral Cortex. (After A. Bethe, taken from A. Van Gehuchten's "Le système nerveux de l'homme," 3d ed., Louvain, 1900, vol. i., p. 302, Fig. 187.)

The descriptions of Apáthy bearing upon the relations of the neurofibrils to sensory surfaces and to the constituent elements of muscular tissue and secreting glands do not concern us here. One important point, however, in connection with his work must be mentioned. He believes that the neuropilum of invertebrates is formed by a huge plexus of anastomosing neurofibrils. This plexus he designates as an "Elementargitter."

Bethe has been able to demonstrate similar fibrils within the protoplasm of the nerve cells of vertebrates, including human beings (Fig. 927). Bethe thinks that he can determine which neurofibrils conduct toward the cell and which conduct away from the cell. He finds that both kinds of fibrils occur in the dendrites of the cells, and argues that a dendrite accordingly carries both cellulipetal and cellulifugal impulses. It must be remembered that many do not believe that it has yet been proved that it is the neurofibril which is the actual conducting element in the nerve cell.

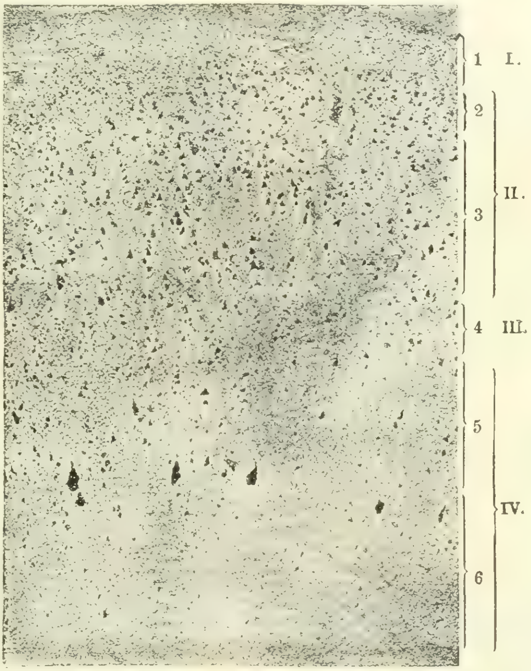

FIG. 928.—Reproduction of a Photogram of a Perpendicular Section through the Tip of the Head of the Gyrus Centralis Anterior, Close to the Falx, of a Healthy Adult Man. Staining by Nissl's method. I. Layer poor in cells. II. Layer of pyramidal cells, containing 2 = layer of small pyramidal cells (= 2. Meynert's layer) + 3 = layer of large pyramidal cells (= 3. Meynert's layer). III. Layer of small cells (= 4. Meynert's layer). IV. Internal (6) and external (5) zone of the layer of medullated fibres (= 5. Meynert's layer). The region marked 5 corresponds to the ganglion-cell layer of Hammarberg, and the region marked 6 to the spindle-cell layer. (After F. Nissl, *Münch. med. Wochenschr.*, Bd. xlv., 1898, S. 1027, Fig. 3.)

Bethe in the main accepts Apáthy's views concerning the structure of the neuropilum of invertebrates, but in opposition to Apáthy denies the occurrence of anastomoses between the individual fibrils.

Nissl accepts the doctrines of Apáthy and Bethe apparently without question and has carried their hypotheses much further than they themselves appear to have been willing to take them. According to a late hypothesis formulated by Nissl, neurofibrils exist outside of the nerve cells and their processes, these being especially abundant in the gray matter of the cerebral cortex. Nissl denies the interpretations of those who have worked with Golgi's method, of the findings met with in silver preparations, and asserts that a large part of the areas between the cell bodies in the cerebral cortex supposed by Golgi workers to be filled up by the multiple subdivisions of dendrites, axones, and collaterals are not in reality so made up, but consist of an immense number of naked neurofibrils situated outside of the cells; these fibrils, Nissl thinks, correspond in a sense to a highly complicated neuropilum. In support of his view he publishes comparative pictures of the motor area of the cerebral cortex of a man (Fig. 928), a dog (Fig. 929), and a mole (Fig. 930). The increased distance between the cells in the higher animals he believes to be accounted for by the increased amount of his hypothetical neuropilum. Nissl was led all the more readily to accept the views of Apáthy and Bethe inasmuch as Becker has also been able to demonstrate fibrillar appearances within "nerve cells" by hæmatoxylin staining.

Still another mode of demonstrating networks of a curious character within the bodies of nerve cells has been introduced by Golgi by a slight modification of his osmic bichromate method. A definite endocellular network apparently different from that described by any previous observer can be demonstrated (Figs. 931 and 932). Veratti has worked with the same method and has been able to impregnate networks in a variety of nerve cells similar to those described by Golgi.

Nucleus.—The nuclei of the nerve cells of the brain agree in structure with those of nerve cells in general (Fig. 933). The nuclei are relatively large and pale, and present in preparations stained by Nissl's method a chromatic membrane and a large deeply staining nucleolus. There is, as a rule, an abundance of achromatic substance. In the nucleolus it is possible in methylene-blue preparations to make out minute deeply staining points, the *nucleoluli* of von Lenhossék. The nucleolus sometimes presents a vacuolated appearance. It is believed by many that each nucleolus consists of a delicate basophile external layer and a central non-basophilic substance. According to Scott each nucleolus is a vesicle with an oxyphile centre and a basophile periphery. In preparations stained by Held's method it is possible to make out in the achromatic parts of the nucleus, strands and masses which take the erythrosin stain. These strands and masses may correspond to the lanthanin of Heidenhain. Careful microchemical studies of the nuclei and nucleoli have been made by Levy. Levy was unable to find nucleoluli in nucleoli stained by Biondi's method. Scott believes that the basophile covering of the nucleolus contains both iron and phosphorus as does also the oxyphile nuclear substance. The latter is readily dissolved in pepsin and hydrochloric acid. It is altered but not dissolved by acids and alkalies, which liberate the iron from it. He believes that the tigroid masses of the cell protoplasm consist of chromatin that has diffused itself from the nucleus into the cytoplasm.

Various authors have proven that the nucleoli of the nerve cells change in size during functional activity. They are small when the cell is at rest, but increase in volume when the cells are active.

The so-called *supporting substances* of the nervous tissue of the brain consist of ependyma cells and neuroglia cells and their derivatives. These cells, it is now believed, are all epiblastic in origin; the doctrine of a mesoblastic neuroglia has been given up. In the earlier stages of development the cells lining the cavities of the central nervous system extend through the whole wall of the neural tube, the peripheral processes being drawn out into long pillars or columns. Later, some of the cells become removed from the central canal; the cell bodies assuming positions at various distances from the central canal somewhere between it and the periphery. Those which remain in connection with the central canal are known in adult life as ependyma cells, while those the cell bodies of which are situated in the nerve substance are known as neuroglia cells. A further origin of neuroglia cells from germinal cells quite like those which give rise to the neuroblasts and true nerve cells is assumed by a number of authors.

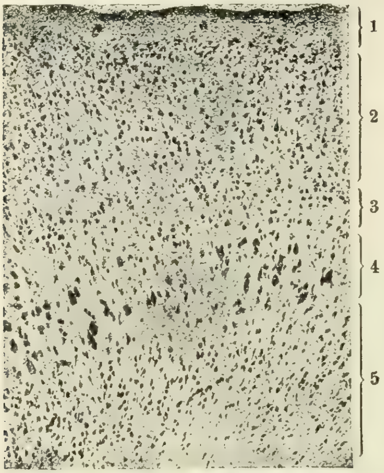

Fig. 929.—Reproduction of a Photogram from a Perpendicular Cortical Section through the Summit of the Gyrus of an Adult Dog, Just in Front of the Sulcus Cruciatus Close to the Falx. Staining by the method of Nissl. 1 = cortical layer free from cells; 2, subdivisible into a narrower external and a broader internal zone, but in no way homological with II. of Fig. 928. On the other hand, 2 in Fig. 928 corresponds to 3 in Fig. 930; 3 in Fig. 928 corresponds to 4 in Fig. 930; (4 + 5) = layer of medullated fibres corresponding to 5 + 6 in Fig. 928, and also to 5 + 6 in Fig. 930. That is, 4 in Fig. 928 corresponds to 5 in Fig. 930, while 5 in Fig. 928 = 6 in Fig. 930. (After F. Nissl, *Münch. med. Wochenschr.*, Bd. xlv., 1898, S. 1027, Fig. 4.)

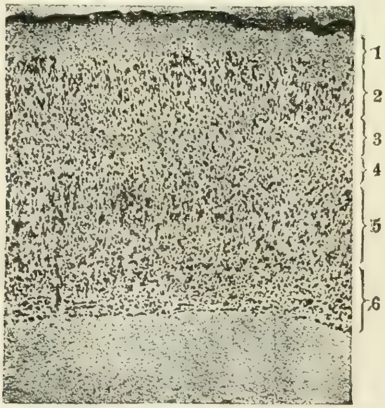

Fig. 930.—Reproduction of a Photogram of a Perpendicular Section through the Cerebral Cortex of a Mole, 1 mm. in Front of the Crucial Suture Close to the Falx. Staining by the method of Nissl. 1 = external layer free from cells; 2, characteristic type of cell arrangement in all cortical areas connected with the olfactorius, especially in the lobus pyriformis; 3 (= 2 of Fig. 929, except the thin cell layer adjoining the cell-free layer, which reminds one still of 2 of Fig 929); 4 (= 3 of Fig. 929); 5 (= 4 of Fig. 929); 6 (= 5 of Fig. 929). (After F. Nissl, *Münch. med. Wochenschr.*, Bd. xlv., 1898, S. 1027, Fig. 5.)

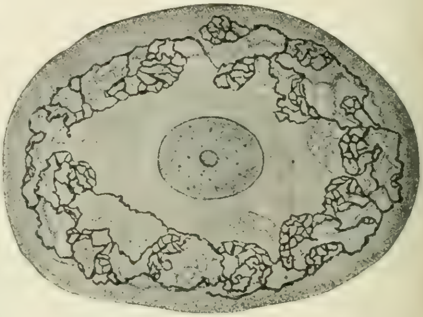

Fig. 931.—Golgi's Endocellular Network. (Taken from A. Van Gehuchten's work.)

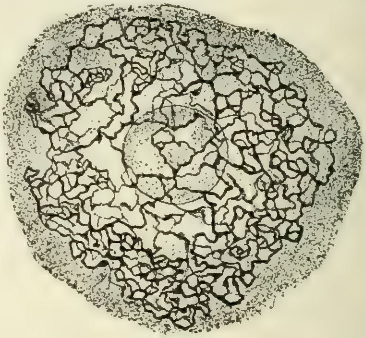

Fig. 932.—Golgi's Endocellular Network. (Taken from A. Van Gehuchten's work.)

The *ependyma cells* have bodies which are cubical or low columnar in shape and long peripheral processes which extend for a shorter or longer distance into the gray and white substance. With ordinary nuclear stains the cell body and its nucleus near the cavity of the ven-

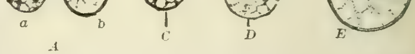

Fig. 933.—Examples of a Variety of Nerve-Cell Nuclei. (After Ramón y Cajal, S., "Textura del sistema nervioso," Madrid, 1899, p. 134, Fig. 43.)

tricles are well seen, but the processes are difficult to make out. In order to demonstrate the latter, the method of Golgi should be employed. With the silver impregnation long strands with short, prickly processes on the surface can be distinguished.

Neuroglia cells as seen in preparations stained by ordinary nuclear dyes are small cells with deeply staining nucleus and surrounded by very little protoplasm (Fig. 934). The cell often appears to be the centre of a radiating system of processes or fibrils. These appearances in freshly teased and stained preparations were carefully investigated by Deiters, and they have since been spoken of as the "spider cells of Deiters." The most careful of the earlier investigations was made by Golgi in 1871. He studied neuroglia chiefly by means of teased preparations and sections, and pictured the glia cells as small elements from which numerous rigid glistening fibres radiated out into the nerve substance. He believed that these fibres did not branch and that they formed no anastomoses. The processes of the glia cells in the gray substance are, according to Golgi, more delicate and less rigid than those in the white substance. The histogenetic position of the glia cells was not understood, however, by Golgi at the time of his earlier work. Although he recognized that the glia fibres differ materially from ordinary connective-tissue fibres, still he believed them to be connective-tissue elements.

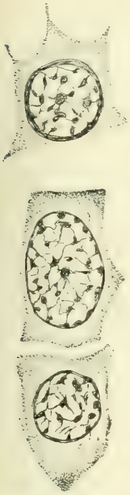
FIG. 934.—Neuroglia Cells. (After Ramón y Cajal, S., "Textura del sistema nervioso," p. 188, Fig. 58.)

A very important advance in our knowledge of glia followed upon the application of the silver chromate method. In preparations thus made the glia cells appear as small black masses from which radiate out into the nervous tissue great numbers of delicate black processes (Fig. 935). These for the most part are unbranched, and do not form anastomoses. While, as a rule, they appear to radiate out in all directions from the periphery of the cell, in other instances the processes project from the two extremities of the cell or even from one extremity only. From the peculiar appearances presented by the radiating processes the name astrocyte has been used as a designation for the cell of Deiters or Golgi to distinguish it from the ependyma cell. Kölliker, who has given very exact descriptions of neuroglia, divides the astrocytes into two principal groups: first, those with long branches (*Langstrahler*); and second, those with short branches (*Kurzstrahler*). The cells with short branches are more abundant in the gray substance and are characterized chiefly by the brevity and delicacy of their radiating processes. Their processes show a marked tendency to varicose swelling in Golgi preparations. They are much more difficult to impregnate with the silver chromate method and often assume a brownish rather than a black color.

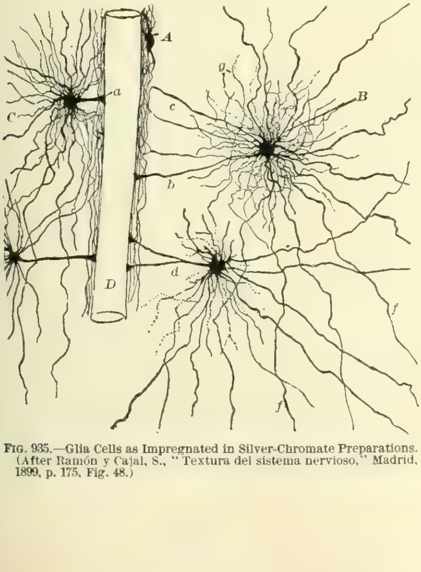

FIG. 935.—Glia Cells as Impregnated in Silver-Chromate Preparations. (After Ramón y Cajal, S., "Textura del sistema nervioso," Madrid, 1899, p. 175, Fig. 48.)

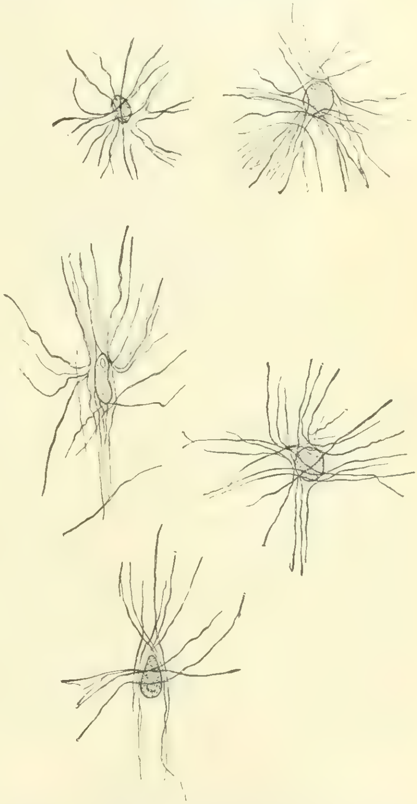
FIG. 936.—Neuroglia Fibrils as Demonstrated by Weigert's Neuroglia Stain. (After Weigert, C., "Der menschliche Neuroglia," Frankfort, 189–.)

The glia cells with long processes occur in different parts of the gray and white substance. They are the typical glia cells which were studied by Deiters and Golgi.

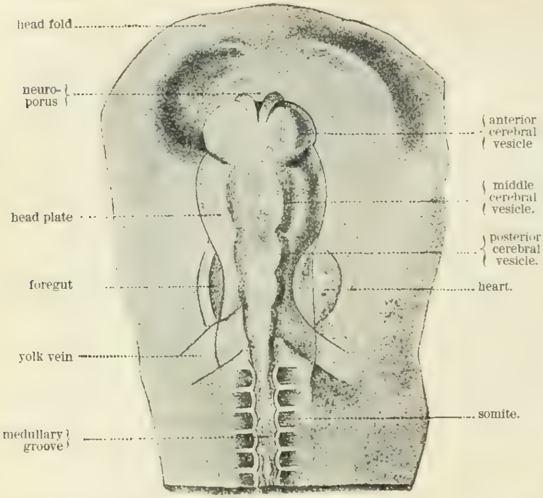

FIG. 937. Anterior Portion of the Body of a Chick, the Head Distinctly Differentiated; seen from the surface. (After J. Kollmann, "Lehrbuch der Entwickelungsgeschichte des Menschen," Jena, 1898, S. 199, Fig. 120.)

Through the use of certain special methods introduced by Mallory, Weigert, and Beneke, appearances are obtained which have led many to the conclusion that the so-called glia fibres are not really processes of the neuroglia cells, but are fibrils which lie upon or which run through the cells. Ranvier was one of the first to promulgate the view that the supporting tissue of the central nervous system presents a similar relation of cells and fibres to that met with in ordinary connective tissue. He asserted that the so-called Deiters' cell as ordinarily described is an artefact, believing that he was able to demonstrate that the fibres looked upon as processes only apparently proceed from the protoplasm of the cell radiating out from the latter as a centre; but in reality are only attached to it. Ranvier's method was very simple. He dissociated with thirty-three-and-one-third-per-cent. alcohol and afterward stained with picrocarmine. In these isolation preparations he convinced himself that the so-called cell processes are not actual prolongations of the protoplasmic body, but represent definitely differentiated fibres which go through the cell body or simply pass over it. Though they radiate out from the cell body as a central point, still the fibres are clinically and morphologically entirely different from the cell bodies.

Weigert's studies of the subject are the most extensive. The neuroglia fibrils by his method stain of a deep blue color and are exquisitely differentiated (Fig. 936). In the so-called astrocytes or Deiters' cells Weigert finds that blue-stained neuroglia fibrils run directly through the protoplasm of the cells, the nuclei of the cells being entirely independent of the fibrils. Weigert feels sure that the fibrils stained by his method do not represent a new, hitherto unknown, structural element, but are identical with what have been described as the processes of Deiters' cells. The fibrils are not chemically identical with the protoplasm, but are composed of an entirely different substance. Nor does this chemical difference between fibres and cell protoplasm appear at any distance from the cell body in the so-called processes of the glia cells, but the differentiation can be made out in the cell body. It is even quite close to the nucleus of the cell. Accordingly, Weigert believes that most of the so-called processes of the cells are in reality not processes, but fibres running through the cells and more or less independent of them. In the embryo they may be regarded as actual processes, but in the adult the differentiation is always demonstrable. Weigert's method shows that the fibres are more or less straight or they may run in stiff curves. They are never markedly tortuous. They are solid, no central cavity being demonstrable in them. They are always smooth, rarely presenting varicosities or moss-like processes. They vary in thickness from extremely fine fibres on the limits of microscopic visibility to fibres 1.5 μ thick. Weigert has never been able to observe division of his fibres nor could he make out in any case the existence of anastomoses.

The arrangement of the various histological elements in the different parts of the brain can best be studied by examining a series of sections taken at different levels and made in various directions. It will be most convenient in this article to study a series of frontal sections passing from the spinal extremity of the brain forward. In describing these sections the nomenclature used will be that of the B. N. A.* Of the three primary cerebral

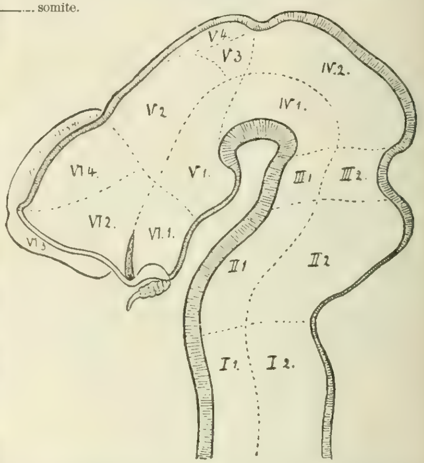

FIG. 938.—Median Section through Embryo Human Brain at the End of the First Month. (After W. His, "Anatomische Nomenclatur," Leipsic, 1895, S. 158, Fig. 17.)

I. Myelencephalon.
I. 1. Pars ventralis. I. 2. Pars dorsalis.
II. Mesencephalon.
II. 1. Pons. II. 2. Cerebellum.
III. Isthmus.
III. 1. Pedunculi cerebri. III. 2. Brachia conjunctiva, vel. med. ant.
IV. Mesencephalon.
IV. 1. Pedunculi cerebri. IV. 2. Corpora quadrigemina.
V. Diencephalon.
V. 1. Pars mammillaris hypothalami. V. 2. Thalamus.
V. 3. Metathalamus.
V. 4. Epithalamus.
VI. Telencephalon.
VI. 1. Pars optica hypothalami. VI. 2. Corpus striatum.
VI. 3. Rhinencephalon.
VI. 4. Pallium.

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* Those who are accustomed to the terms employed by Professor Wilder will find the equivalents of the terms of the Basle Commission

vesicles the first gives rise to the forebrain or telencephalon and the interbrain or diencephalon, the second to the midbrain or mesencephalon, and the third to the rhombencephalon. The relations of these parts are shown in the accompanying figures (Figs. 937, 938, and 939). Perhaps the classification which follows will be found most satisfactory. It is that introduced by His of Leipsic. The encephalon or brain is divisible into the cerebrum and the rhombencephalon. The rhombencephalon in turn includes the myelencephalon, the metencephalon, and the isthmus rhombencephali. The myelencephalon corresponds to the medulla oblongata, the metencephalon to the pons and cerebellum. The cerebrum is divisible into the mesencephalon and prosencephalon. The mesencephalon includes the pedunculi cerebri and the corpora quadrigemina. The prosencephalon is divisible into the diencephalon or interbrain and the telencephalon or endbrain. The diencephalon includes the pars mamillaris hypothalami and the thalamencephalon, the thalamencephalon in turn including the thalamus, the metathalamus, and the epithalamus. The telencephalon includes the hemisphærium and the pars optica hypothalami. The hemisphærium is made up of the pallium, the corpus striatum, and the rhinencephalon. These relations are presented below in tabular form:

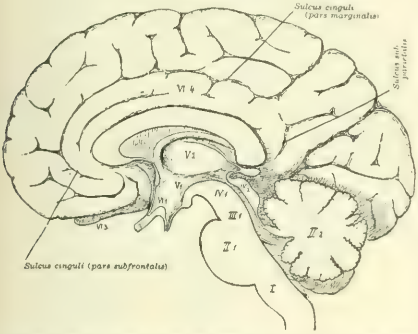
Sulcus cinguli (pars marginalis)
Sulcus subparietalis
VI 4
V1
V1
VI1
IV1
III1
II2
II1
VI3
I
Sulcus cinguli (pars subfrontalis)

FIG. 939.—Median Section through Fœtal Human Brain of the Third Month. (After His, *Arch. f. Anat. u. Physiol.*, Anat. Abth., 1892.) Lettering same as in Fig. 938 (*vide supra*).

Posterior cerebral vesicle.	I. Medulla oblongata		**Myelencephalon I.** (Afterbrain).		**Rhombencephalon I.-III.** (*Rautenhirn*).	**Encephalon I. VI.** (Brain).
	II$_1$. Pons		**Metencephalon II.** (Hindbrain).			
	II$_2$. Cerebellum					
	III.		**Isthmus rhombencephali III.**			
Middle cerebral vesicle.	IV$_1$. Pedunculi cerebri		**Mesencephalon IV.** (Midbrain).		**Cerebrum IV.—VI.** (*Grosshirn*).	
	IV$_2$. Corpora quadrigemina					
Anterior cerebral vesicle.	V$_1$. Pars mammillaris hypothalami (Hypothalamus vice pars mam. and pars optica).		**Diencephalon V.** (Interbrain).	**Prosencephalon V. and VI.** (Forebrain).		
	V$_2$. Thalamus	Thalamencephalon V$_2$ V$_4$.				
	V$_3$. Metathalamus					
	V$_4$. Epithalamus					
	VI$_1$. Pars optica hypothalami		**Telencephalon VI.** (Endbrain).			
	VI$_2$. Corpus striatum	Hemisphærium VI$_2$ VI$_4$.				
	VI$_3$. Rhinencephalon					
	VI$_4$. Pallium					

In describing sections through these various parts it will be necessary, in order to make clear the connections of all, to begin with a section of the spinal cord in the cervical region.

If we begin with a schematic transverse section through the cervical portion of the spinal cord it will be easy to localize the main features of the cross section and to connect these with the parts met with in sections higher up. In this section (Fig. 940) only one-half of the cord is shown. In the middle line in front is seen the *fissura mediana ventralis*, the *commissura ventralis alba* (*Ca*), the *commissura grisea*, containing the *canalis centralis* surrounded by the *substantia gelatinosa centralis* (*Sgc*); behind is the *septum medianum dorsalis* separating Goll's fasciculi of the two sides. In the half of the cord shown, the gray substance is seen to be completely surrounded by the white substance. The white substance consists of the three funiculi, the *funiculus ventralis* in front, the *funiculus lateralis* at the side, and the *funiculus dorsalis* behind. The funiculus ventralis includes the *fasciculus cerebro-spinalis ventralis* or ventral pyramidal tract (*PyV*), the *fasciculus ventralis proprius* or ventral ground bundle (*Vg*), and the *fasciculus sulco-marginalis* (*vm*). The funiculus lateralis includes the *fasciculus spino-cerebellaris dorso-lateralis* or direct cerebellar tract (*KS*), the *fasciculus ventro-lateralis Gowersi* or Gowers' tract (*G*), the *fasciculus cerebro-spinalis lateralis* or lateral pyramidal tract (*PyS*), the *fasciculus Lissaueri* (*L*), the *fasciculus lateralis limitans* or lateral limiting layer (*SG*), the *fasciculus lateralis proprius* or lateral ground bundle (*GSZ iS*). The funiculus dorsalis includes the *fasciculus gracilis* or Goll's fasciculus (*GS*) and the *fasciculus cuneatus* or Burdach's fasciculus (*B*). Goll's fasciculus is separated from Burdach's fasciculus by the *septum paramedianum*. The region of Schultze's comma in the dorsal funiculus is designated as *SC*.

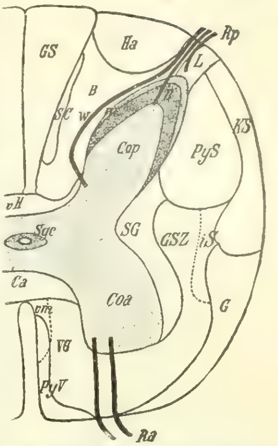

FIG. 940.—Schematic Transverse Section through the Pars Cervicalis of the Medulla Spinalis. (After H. Obersteiner, "Anleitung beim Studium des Baues der nervösen Centralorgane," iii. Aufl., Leipz. u. Wien, 1896, S. 257, Fig. 113.) *B*, Fasciculus cuneatus Burdachi; *Ca*, commissura ventralis; *Coa*, cornu ventralis; *Cop*, cornu dorsalis; *G*, fasciculus ventro-lateralis Gowersi; *GS*, fasciculus gracilis Golli; *GSZ*, mixed bundle of funiculus lateralis; *Ha*, dorso-lateral field of funiculus dorsalis; *iS*, intermediary bundle of funiculus lateralis; *KS*, fasciculus cerebello-spinalis or direct cerebellar tract of Flechsig; *L*, Lissauer's fasciculus; *m*, marginal zone; *PyS*, fasciculus cerebro-spinalis lateralis or lateral pyramidal tract; *PyV*, fasciculus cerebro-spinalis ventralis or ventral pyramidal tract; *R*, substantia gelatinosa Rolandi; *Ra*, radix ventralis; *Rp*, radix dorsalis; *SC*, comma of Schultze; *SG*, lateral limiting layer; *Sgc*, substantia gelatinosa centralis; *VG*, fasciculus ventralis proprius; *vH*, ventral field of dorsal funiculi; *vm*, fasciculus sulco-marginalis; *w*, dorsal root fibre.

The gray matter is divisible in this region into a ventral and a dorsal column. The *columna ventralis* (*Coa*), often spoken of as the ventral horn or anterior horn, contains the motor cells; the *columna dorsalis* (*Cop*), often

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in Professor Wilder's article entitled "Neural Terms—International and National." Journ. Comp. Neurol., Granville, vol. vi. (1896), pp. 216-352.

called the dorsal horn or posterior horn, contains a large number of small cells, probably sensory. The entering dorsal root, *radix dorsalis* (*Rp*), and the issuing ventral root, *radix ventralis* (*Ra*), are shown. The lateral horn is not well illustrated in the schematic figure.

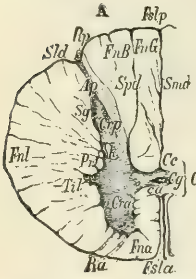

Fig. 941.—Cross Section through the Human Spinal Cord, Stained with Carmine. (After H. Obersteiner, "Anleitung beim Studium des Baues der nervösen Centralorgane im gesunden und kranken Zustande," iii. Aufl., Leipzig und Wien, 1896, S. 227, Figs. 96–102.) A, Transverse section at the level of C iii; *Cg*, commissura grisea; *Ap*, apex columnæ dorsalis; *Ca*, commissura ventralis alba; *Cc*, canalis centralis; *Cm*, commissura medullæ spinalis; *Cra*, cornu ventralis; *Crp*, cornu dorsalis; *Fna*, funiculus ventralis; *FnB*, fasciculus cuneatus Burdachi; *FnG*, fasciculus gracilis Golli; *Fnl*, funiculus lateralis; *Fsla*, fissura mediana ventralis; *Fslp*, sulcus medianus dorsalis; *k*, tractus solitarius; *Pr*, formatio reticularis; *Ra*, radix ventralis; *Rp*, radix dorsalis; *Sg*, substantia gelatinosa Rolandi; *Sld*, sulcus lateralis dorsalis; *Smd*, septum medianum dorsale; *Spd*, septum intermedium dorsale; *Til*, tractus intermedio lateralis.

The more exact relations at the level of the third cervical nerve are shown in Fig. 941. The legend will explain the various parts sufficiently.

A little higher up, just at the junction of the cervical spinal cord with the medulla oblongata, the relations of the gray matter to the white matter change considerably. In Fig. 942 one can easily make out that the gray matter is more abundant than at the lower level, that the dorsal horns of gray matter are inclined much more lateralward instead of dorsalward, while the neck of gray matter connecting the dorsal horn with the rest of the gray matter is very long and narrow. In the region of the lateral horn of gray matter the white and gray matter are much mixed up, corresponding to the beginning of the formatio reticularis of the medulla oblongata.

A section taken through one side of the central nervous system of the new-born babe at the junction of the cervical portion of the spinal cord with the medulla oblongata will show certain particulars not brought out in previous sections (see Fig. 943). Here not all the white matter is medullated. Thus, for example, the fibres of the pyramidal tract are not yet surrounded by myeline sheaths. In the centre is seen the *canalis centralis*; ventral from it is a white area corresponding to the non-medullated decussation of the pyramids (*decussatio pyramidum*); dorsal from the central canal is a mass of gray matter and a median dorsal septum and sulcus. The ventral part of the section has been cut off so that the gray matter of the ventral horn is not well shown. That of the dorsal horn (*columna dorsalis*) is, however, well illustrated. It is directed, however, far lateralward instead of backward, and is capped by a large mass of gelatinous substance (*substantia gelatinosa Rolandi*). Between the dorsal horn and the median line are two new masses of gray matter not met with in the spinal cord lower down; one very well developed, occupying a large part of the region of the funiculus gracilis, is called the *nucleus funiculi gracilis* or Goll's nucleus. Lateral from it, in the ventral part of the fasciculus cuneatus, a mass of gray matter is beginning to appear which higher up becomes very voluminous and is known as the *nucleus funiculi cuneati* or Burdach's nucleus. The white matter surrounds the gray matter as before, and is again divisible into the funiculus ventralis, the funiculus lateralis, and the funiculus dorsalis. The funiculus ventralis includes the non-medullated pyramid and the partly medullated fasciculus ventralis proprius. The funiculus lateralis includes the partially medullated fasciculus ventralis proprius, the well-medullated fasciculus spino-cerebellaris dorso-lateralis. In the funiculus dorsalis are seen the well-medullated fasciculus gracilis and the well-medullated fasciculus cuneatus. Passing transversely lateralward through the gray matter and through the

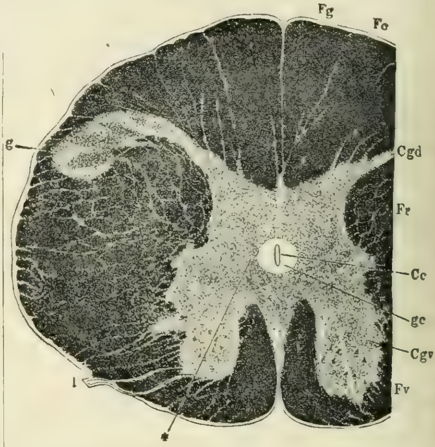

Fig. 942.—Transverse Section at the Junction of the Medulla Spinalis with the Medulla Oblongata. (After J. Henle, "Handbuch der Nervenlehre des Menschen," zweite Aufl., Braunschweig, 1879, S. 208, Fig. 124.) *Cc*, Canalis centralis; *Cgd*, columna (grisea) dorsalis; *Cgv*, columna (grisea) ventralis; *Fv*, funiculus ventralis; *Fc*, fasciculus cuneatus; *Fg*, fasciculus gracilis; *g*, substantia gelatinosa Rolandi; *gc*, substantia gelatinosa centralis; *I*, ventral root of the first cervical nerve; the asterisk * indicates a cross section of a blood-vessel; *Fr*, formatio reticularis. This section is below the level of the decussatio pyramidum.

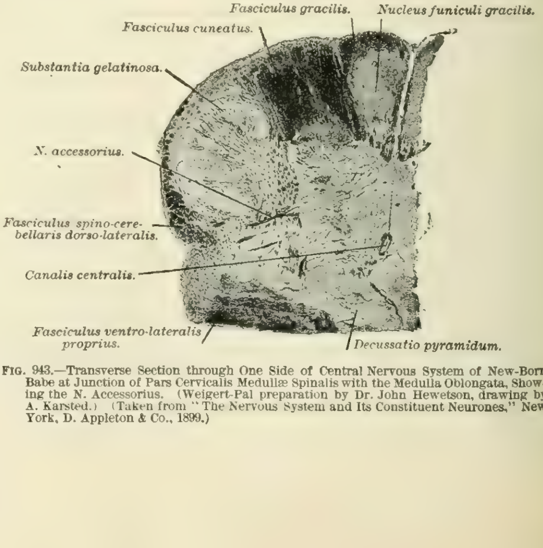

Fig. 943.—Transverse Section through One Side of Central Nervous System of New-Born Babe at Junction of Pars Cervicalis Medullæ Spinalis with the Medulla Oblongata, Showing the N. Accessorius. (Weigert-Pal preparation by Dr. John Hewetson, drawing by A. Karsted.) (Taken from "The Nervous System and Its Constituent Neurones," New York, D. Appleton & Co., 1899.)

funiculus lateralis are seen the root fibres of the accessory nerve (*radix nervi accessorii*). A good deal of white matter mixed up with gray matter is visible in the lateral region.

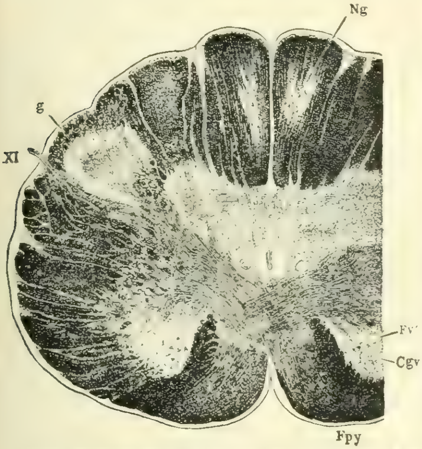

FIG. 944. Transverse Section through the Medulla Oblongata at the Level of the Decussatio Pyramidum. (After J. Henle, "Handbuch der Nervenlehre des Menschen," Zweite Aufl., Braunschweig, 1879, S. 211, Fig. 126.) *Cgv*, Columna (grisea) ventralis or ventral horn; *Fv′*, continuation in the medulla of the fasciculus ventralis proprius (*Vorderstrangrest* of the Germans); *Fpy*, fasciculi cerebro-spinales pyramidales undergoing decussation; *g*, substantia gelatinosa Rolandi; *Ng*, spinal extremity of nucleus funiculi gracilis; *XI*, nervus accessorius.

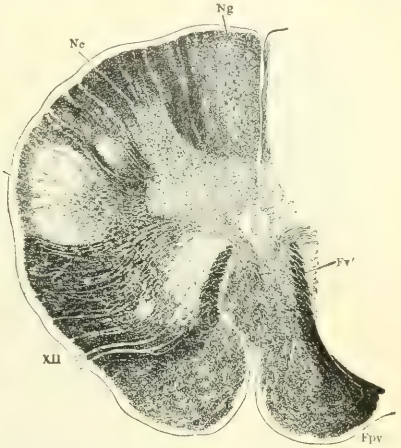

FIG. 945.—Transverse Section through the Medulla Oblongata at the Level of the Most Caudal Fila Radicularia of the Nervus Hypoglossus. (After J. Henle, "Handbuch der Nervenlehre des Menschen," Zweite Aufl., Braunschweig. 1879, S. 213, Fig. 127.) *Fv′*, Continuation in the Medulla of the fasciculus ventralis proprius of the spinal cord; *Fpy*, pyramis (at uppermost level of decussatio pyramidum); *g*, substantia gelatinosa; *Nc*, nucleus funiculi cuneati (Burdachi); *Ng*, nucleus funiculi gracilis (Golli). The decussatio lemniscorum is not indicated in the figure, though it is to be seen at this level.

This corresponds to the beginning of the *formatio reticularis.* A section from a similar region in the adult is shown in Fig. 944. In this figure the decussation of the pyramids is well marked.

At a little higher level (Fig. 945), the relations of the gray matter to the white matter have become still more complex. The fasciculus gracilis is almost entirely replaced by the nucleus funiculi gracilis, and the funiculus cuneatus is much encroached upon by the nucleus funiculi cuneati. The region of the lateral funiculus is being converted largely into a mass of formatio reticularis. The substantia gelatinosa Rolandi has increased in bulk, and between it and the surface lie, instead of the fasciculus of Lissauer met with in the spinal cord, the descending fibres of the spinal tract of the trigeminal nerve (*tractus spinalis nervi trigemini*).

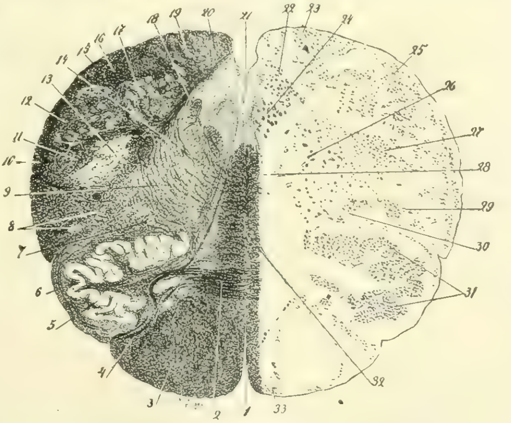

FIG. 946.—Transverse Section through the Medulla Oblongata in the Region of the Distal Portion of the Fossa Rhomboidea of an Adult Human Being. The nerve fibres have been drawn in on the left side (Weigert-Wolters' staining); on the right side, the cells (Nissl's stain). (After E. Flatau, "Atlas Cerebri Humani," Tab. x., Fig. B.) 1, Fissura longitudinalis mediana; 2, stratum interolivare lemnisci; 3, pyramis; 4, radix nervi hypoglossi; 5, nucleus olivaris inferior; 6, fibræ arcuatæ superficiales laterales; 7, nucleus olivaris accessorius dorsalis; 8, nucleus lateralis; 9, substantia reticularis grisea with fibræ arcuatæ internæ; 10, fibræ arcuatæ superficiales laterales; 11, tractus spinalis nervi trigemini; 12, corpus restiforme; 13, substantia gelatinosa; 14, nervus hypoglossus; 15, fibræ arcuatæ superficiales dorsales; 16, funiculus cuneatus Burdachi; 17, nucleus funiculi cuneati; 18, tractus solitarius; 19, nucleus funiculi gracilis; 20, funiculus gracilis Golli; 21, distal part of fossa rhomboidea; 22, nucleus alæ cinereæ; 23, nucleus funiculi gracilis; 24, nucleus nervi hypoglossi; 25, nucleus funiculi cuneati; 26, scattered cells of the formatio reticularis grisea; 27, substantia gelatinosa; 28, dorsal part of substantia reticularis alba (fasciculus longitudinalis medialis); 29, nucleus lateralis; 30, cells of the nucleus olivaris accessorius dorsalis; 31, cells of the nucleus olivaris inferior; 32, raphe with the stratum interolivare lemnisci on each side of it. On both sides of the raphe lie some scattered small cells; 33, cells of the nuclei arcuati. Some large cells which lie in the region between the dorsal accessory olive (30) and the substantia gelatinosa (27) belong to the nucleus ambiguus.

In a section at a higher level (Fig. 946) the central canal has opened out into the lower part of the fourth ventricle. Below the stratum griseum centrale is the nucleus nervi hypoglossi (24). Just dorsad from this nucleus is situated part of the nucleus alæ cinereæ (22), while more laterally and dorsally placed is seen the upward continuation of the nucleus funiculi gracilis (19, 23); some fibres of the funiculus gracilis are still present (20). Still more lateralward is seen the upward continuation of the funiculus cuneatus (16), and ventrad from this the nucleus funiculi cuneati (17, 25). Curving around the funiculus cuneatus are a few of the fibræ arcuatæ superficiales dorsales. More ventrally situated is the corpus restiforme (12), here consisting chiefly of the upward continuation of the direct cerebellar tract from the spinal cord. The pale mass of substantia gelatinosa is visible at 13, while lateralward from it are seen in transverse section the descending fibres of the tractus spinalis nervi trigemini (11). Just lateralward from this are more lateral superficial arcuate fibres (10); ventralward from the substantia gelatinosa are situated the nuclei laterales (8, 29). In the zone between the area above described and the radix n. hypoglossi (4, 14) are seen the following structures: the tractus solitarius (18), which represents chiefly descending fibres from the nervus glosso-pharyngeus, the formatio reticularis with many fibræ arcuatæ internæ (9), the nucleus olivaris accessorius dorsalis (7, 30), the nucleus olivaris inferior (5, 31), and the fibræ arcuatæ superficiales laterales (6). In the middle line is seen the raphe extending from the fissura longitudinalis ventralis (1) to the floor of the fourth ventricle (21). From the dorsal surface ventralward between the raphe and the radix n. hypoglossi the following structures are met with: Below the gray matter are seen in transverse section the fibres of the fasciculus longitudinalis medialis. Ventral from this are the transverse sections of the fibres of the stratum interolivare lemnisci which are made up of internal arcuate fibres which have crossed the raphe and turned to run longitudinally. Among these fibres some small cells are present (32). At the most ventral part of the interolivary layer of the lemniscus are seen many transverse fibres; at the level of the olive (2) the large bundle of white fibres on the ventral surface is the pyramis (3). At the periphery of the pyramid a few cells are seen which represent a continuation downward of the nuclei arcuati of the pons.

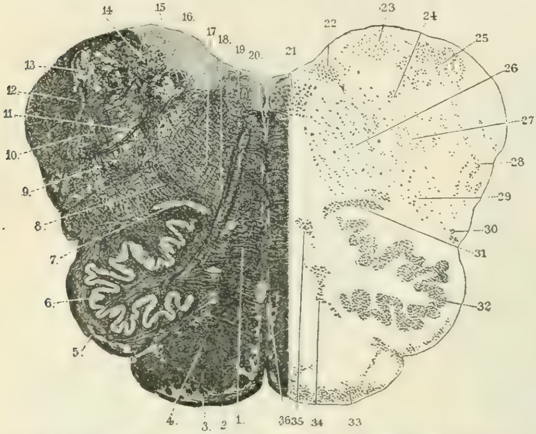

FIG. 947.—Transverse Section through the Medulla Oblongata in the Region of the Nucleus Nervi Hypoglossi and Nucleus Alæ Cinereæ in an Adult Human Being. On the left side the fibres are photographed (Weigert-Wolters' stain); on the right side the cells have been drawn in from Nissl preparations. (After E. Flatau, "Atlas Cerebri Humani," Tab. xi., Fig. A.) 1, Stratum interolivare lemnisci; 2, fibræ arcuatæ superficiales ventrales; 3, nuclei arcuati; 4, pyramis; 5, fibræ arcuatæ superficiales lateralis; 6, nucleus olivaris inferior; 7, nucleus olivaris accessorius dorsalis; 8 and 9, fibræ arcuatæ internæ; 10, tractus spinalis nervi trigemini; 11, nervus vagus; 12, corpus restiforme; 13, nucleus funiculi cuneati; 14, remains of the nucleus funiculi gracilis and bundles of the radix descendens nervi vestibuli; 15, tractus solitarius; 16, nucleus alæ cinereæ; 17, formatio reticularis grisea; 18, nervus hypoglossus; 19, nucleus nervi hypoglossi; 20, raphe; 21, nucleus nervi hypoglossi; 22, nucleus nervi vagi; 23, nucleus nervi vestibuli; 24, groups of cells which belong partly to the nucleus funiculi cuneati and partly to the nucleus tractus solitarii; 25, nucleus funiculi cuneati; 26, scattered cells in the formatio reticularis grisea; 27, cells of the substantia gelatinosa; 28, cells of the nucleus lateralis; 29, cells of the nucleus ambiguus; 30, cells of the nucleus lateralis; 31, cells of the nucleus olivaris accessorius dorsalis; 32, cells of the nucleus olivaris inferior; 33, cells of the nuclei arcuati; 34 and 35, cells of the nucleus olivaris accessorius medialis; 36, nuclei arcuati.

If a section be taken still higher up the relations become somewhat more complex (see Fig. 947). The fourth ventricle has become much wider, the two halves of the medulla are separated

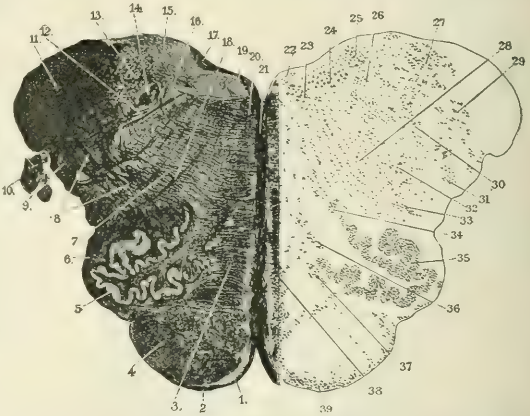

FIG. 948.—Transverse Section through the Medulla Oblongata at the Level of the Nervus Vagus and Nervus Glosso-Pharyngeus in an Adult Human Being. On the left side, photograph of a fibre preparation; on the right side the cells have been drawn in from Nissl preparations. (After E. Flatau, "Atlas Cerebri Humani," Tab. xi., Fig. 13.) 1, Nuclei arcuati; 2, fibræ arcuati superficiales ventrales; 3, stratum interolivare lemnisci; 4, pyramis; 5, nucleus olivaris inferior; 6, fibræ arcuatæ superficiales laterales; 7, formatio reticularis grisea with fibræ arcuatæ internæ; 8, fibræ cerebello-olivares; 9, tractus spinalis nervi trigemini; 10, extra-medullary bundle of the nervus vagus and nervus glosso-pharyngeus; 11, corpus restiforme; 12, bundle of the nervus glosso-pharyngeus (the radial fibres running medial from this and not lettered represent the motor fibres of the vagus and glosso-pharyngeal nerves); 13, radix descendens nervi vestibuli; 14, tractus solitarius; 15, nucleus nervi vestibuli; 16, nucleus nervi glosso-pharyngei; 17, striæ medullares; 18, radial fibres in the formatio reticularis grisea (at the boundary between the fibræ arcuatæ internæ and the fibræ cerebello-olivares); 19, nucleus funiculis teretis; 20, fasciculus longitudinalis medialis; 21, raphe; 22, nucleus funiculi teretis; 23, cells which lie dorsalward from the fasciculus longitudinalis medialis and belong to the cells of the formatio reticularis grisea; 24, nucleus nervi vagi; 25, nucleus nervi vestibuli medialis; 26, nucleus nervi glosso-pharyngei; 27, cells of the nucleus nervi vestibuli lateralis (Deiters) and of the remains of the dorsal horn of the spinal cord; 28, scattered cells of the formatio reticularis grisea; 29, cells belonging to 27; 30, cells of the substantia gelatinosa; 31, nucleus lateralis; 32, cells of the nucleus ambiguus; 33, nucleus lateralis (?); 34, cells of the nucleus olivaris accessorius dorsalis; 35, 36, 37, cells of the nucleus olivaris inferior; 38, 39, cells of the nuclei arcuati.

from each other by the raphe (20). In the floor of the fourth ventricle, passing from the middle line lateralward, are seen the nucleus n. hypoglossi (19, 21), the nucleus alæ cinereæ (16, 22), the tractus solitarius (15), and the lower portion of the nucleus n. vestibuli (23), near which are a few fibres of the fasciculus cuneatus and some fibres of the radix descendens n. vestibuli (14). Each half of the medulla is divisible by means of the radix n. vagi and the radix n. hypoglossi into three compartments: one lateral between the dorso-lateral edge and the radix n. vagi, one middle between the radix n. vagi and the radix n. hypoglossi, and one medial between the radix n. hypoglossi and the raphe.

In the lateral compartment can be seen the corpus restiforme (12), the nucleus funiculi cuneati (13, 25), the tractus spinalis n. trigemini (10), and the substantia gelatinosa (27).

In the middle compartment there are the fibræ arcuatæ superficiales laterales (5), the nucleus olivaris inferior (6, 32), the nucleus olivaris accessorius dorsalis (7, 31), the fibræ arcuatæ internæ (8, 9), the formatio reticularis grisea (17, 26), the nuclei laterales (28), and the nucleus ambiguus (29) which is regarded as the motor nucleus of origin of the n. vagus and the n. glosso-pharyngeus.

In the medial compartment, passing from the dorsal surface ventralward, is seen the stratum interolivare lemnisci (1), the ventral superficial arcuate fibres (2), the pyramis (4), the nuclei arcuati (3), and the nucleus olivaris accessorius medialis (34, 35).

In the next section (Fig. 948), taken from the upper part of the medulla oblongata, the fourth ventricle is very wide and the corpus restiforme has become very markedly developed. In the floor of the fourth ventricle, passing from the middle line lateralward, are seen the nucleus funiculi teretis (19, 22), the nucleus alæ cinereæ (24), the striæ medullares or striæ acustici (17), the nucleus n. vestibuli medialis (15, 25). The corpus restiforme (11) is seen as a large mass of fibres cut transversely at the lateral dorsal angle of the cross section. Just medial to it are seen the bundles of the radix descendens n. vestibuli (13). In many of these bundles are masses of gray matter (27) which represent chiefly the nuclei of the descending root of the vestibular nerve. The round bundle formed by the tractus solitarius (14) is clearly visible, and close to it the nucleus tractus solitarii (26); at 9 the tractus spinalis n. trigemini is seen crossed by black bundles of fibres, the fibræ cerebello-olivares (8). Medial from the tractus spinalis n. trigemini are situated the cells of the substantia gelatinosa (30). The nucleus lateralis (31) is still visible. The motor nucleus of the n. vagus and of the n. glosso-pharyngeus, or so-called nucleus ambiguus, is visible. At this level (33) the fibræ arcuatæ internæ (7) are numerous, crossing the formatio reticularis grisea and running toward the raphe. The nucleus olivaris inferior (5, 35) is accompanied by the nucleus olivaris accessorius dorsalis (34) and the nucleus olivaris accessorius medialis (37). Dorsolateral from the olive are the fibræ arcuatæ superficiales laterales. In the middle line is seen the raphe and close to it the fasciculus longitudinalis medialis (20), the stratum interolivare lemnisci (3), and the pyramis (4); running around the pyramid are the fibræ arcuatæ superficiales ventrales (2), and the nuclei arcuati (1, 38, 39).

The section which follows (Fig. 949) is taken at the uppermost part of the medulla oblongata just where it goes over into the pons. Here the fourth ventricle is at its widest, and running transversely across it are seen the striæ medullares (16). Connected lateralward with the nucleus n. cochleæ dorsalis or tuberculum acusticum (14) is the n. cochleæ. In the floor of the fourth ventricle, passing from the middle line lateralward, can be seen some cells of the nucleus reticularis tegmenti (24) and the nucleus n. vestibuli medialis (19, 26). The corpus restiforme (15) is separated from the periphery by the dorsal cochlear nucleus (14, 29); medial from it the radix descendens n. vestibuli is present in the form of numerous discrete bundles in among which are situated the large multipolar ganglion cells of Deiters' nucleus (nucleus n. vestibuli lateralis) (27). Ventral from the corpus restiforme and the radix descendens n. vestibuli are seen the root fibres of the n. glosso-pharyngeus (17). A portion of the nucleus n. cochleæ ventralis is visible (12, 31). Ventralward from the root fibres of the glosso-pharyngeal nerve are seen the fibres of the tractus spinalis n. trigemini (10), and medial from them the cells of the substantia gelatinosa (11, 28). The formatio reticularis (20) is well developed. It is crossed as in the sections below by many fibræ arcuatæ internæ (8); the fibræ cerebello-olivares are still visible (9). The section passes through the upper part of the nucleus olivaris inferior (5) and a portion of the nucleus olivaris accessorius dorsalis (21, 35). The fibræ

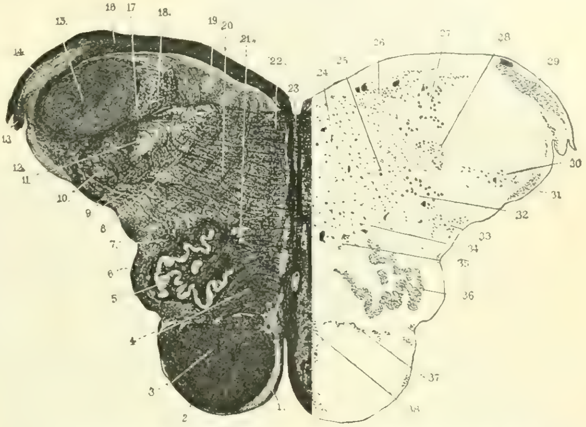

FIG. 949. Transverse Section through the Proximal Part of the Medulla Oblongata at the Region of Entrance of the Nervus Acusticus in an Adult Human Being. On the left the fibres have been photographed; on the right the cells have been drawn in. (After E. Flatau, "Atlas Cerebri Humani," Tab. xii., Fig. A.) 1, Nuclei arcuati; 2, fibræ arcuatæ superficiales ventrales; 3, pyramis; 4, stratum interolivare lemnisci; 5, nucleus olivaris inferior; 6, fibræ arcuatæ superficiales laterales; 7, fasciculus tegmenti centralis, or centrale Haubenbahn of von Bechterew; 8, fibræ arcuatæ internæ; 9, fibræ cerebello-olivares; 10, tractus spinalis nervi trigemini; 11, substantia gelatinosa; 12, nucleus nervi cochleæ ventralis; 13, nervus cochleæ; 14, nucleus nervi cochleæ dorsalis (tuberculum acusticum); 15, corpus restiforme; 16, striæ medullares (very markedly developed); 17, radix nervi glosso-pharyngei; 18, radix descendens nervi vestibuli; 19, nucleus nervi vestibuli medialis; 20, formatio reticularis grisea; 21, stratum interolivare lemnisci; 22, fasciculus longitudinalis medialis; 23, raphe; 24, cells dorsal from the fasciculus longitudinalis medialis connected with the nucleus reticularis tegmenti; 25, scattered cells of the tegmentum (von Bechterew's nucleus reticularis tegmenti); 26, nucleus nervi vestibuli medialis; 27, nucleus nervi vestibuli lateralis (Deiters); 28, cells of the substantia gelatinosa; 29, cells of the tuberculum acusticum; 30, tongue-like collection of cells; 31, ventro-medial continuation of the nucleus nervi cochleæ ventralis; 32, nucleus nervi facialis; 33, nucleus lateralis; 34, large multipolar cells (connected with the scattered cells of the formatio reticularis grisea); 35, nucleus olivaris accessorius dorsalis; 36, cells of nucleus olivaris inferior; 37, scattered cells at the dorsal periphery of the pyramid (beginning nuclei pontis); 38, cells of the nuclei arcuati.

arcuatæ superficiales laterales are still present (6), and dorso-lateral from the olive are seen some of the fibres of the fasciculus tegmenti centralis or centrale Haubenbahn of von Bechterew (7). A good many fibres run longitudinally in the raphe (23). The fasciculus longitudinalis medialis (22) is larger than in the sections below. The stratum interolivare lemnisci (4) is highly developed just before going over into the lemniscus medialis of the pons. The pyramis (3) is large, is surrounded by the fibræ arcuatæ superficiales ventrales, and has close to it the nuclei arcuati (1, 38).

In sections through the pons we have to distinguish between the pars dorsalis pontis and the pars basilaris pontis. The pars basilaris pontis includes the large fasciculi longitudinales of the pons, the large bundles of transverse fibres of the pons, and the great gray masses known as the nuclei pontis. The pars dorsalis pontis includes the upward continuation of the medulla oblongata with the exception of the pyramids. It contains the nuclei of the nerves connected with the pons, the fasciculus longitudinalis medialis, the medial and lateral lemnisci, the corpus trapezoideum, the formatio reticularis and the superior olivary complex. In Fig. 950 some of the principal structures of the lower part of the pons are shown.

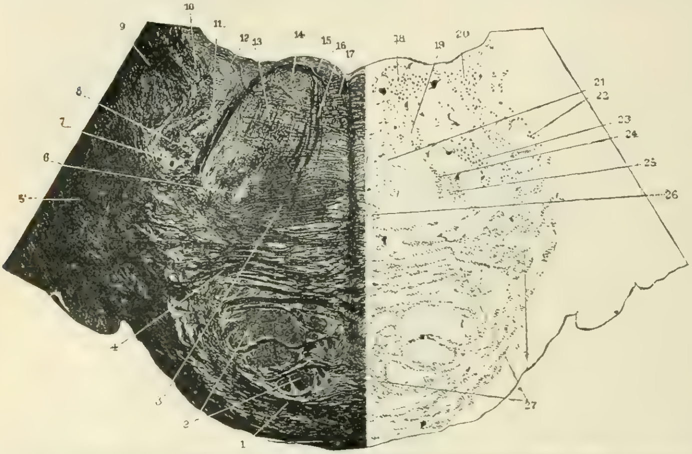

FIG. 950. Transverse Section through the Pons at the Level of the Nervus Facialis and Nervus Abducens in an Adult Man. On the left side the fibres have been photographed; on the right the cells have been drawn in. (After E. Flatau, "Atlas Cerebri Humani," Berlin, 1899, Tab. xii., Fig. B.) 1, Fibræ pontis superficiales; 2, fasciculi longitudinales pontis; 3, lemniscus medialis; 4, fibræ pontis profundæ; 5, brachium pontis; 6, nucleus olivaris superior; 7, substantia gelatinosa (beginning sensory nucleus of the trigeminus); 8, tractus spinalis nervi trigemini; 9, corpus restiforme (ascending to cerebellum); 10, radix descendens nervi vestibuli; 11, radix nervi facialis pars secunda; 12, nucleus nervi vestibuli medialis; 13, formatio reticularis grisea with ascending fibres from the nucleus nervi facialis and fibres from the nucleus olivaris superior to the nucleus nervi abducentis; 14, nucleus nervi abducentis; 15, genu internum nervi facialis; 16, nervus abducens; 17, fasciculus longitudinalis medialis; 18, nucleus nervi abducentis; 19, cells of formatio reticularis grisea; 20, nucleus nervi vestibuli lateralis Deiters; 21, nucleus reticularis tegmenti von Bechterew; 22, cells of the substantia gelatinosa; 23, cells of the proximal part of the nucleus nervi facialis or of the distal motor nucleus of the nervus trigeminus; 24 and 25, cells of the nucleus olivaris superior; 26, continuation of the nuclei pontis in the tegmentum; 27, nuclei pontis.

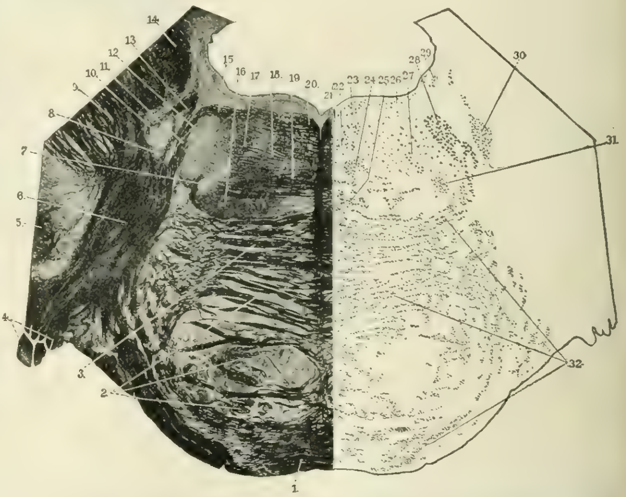

FIG. 951.—Transverse Section through the Pons at the Level of the Nervus Trigeminus in an Adult Human Being. On the left side the fibres have been photographed; on the right side the cell bodies have been drawn in. (After E. Flatau, "Atlas Cerebri Humani," Tab. xiii., Fig. A) 1, Fibræ superficiales pontis; 2, fasciculi longitudinales pontis; 3, fibræ pontis profundæ; 4, radix nervi trigemini; 5, brachium pontis; 6, radix nervi trigemini; 7, nucleus olivaris superior; 8, radix nervi trigemini pars sensorius; 9, corpus restiforme; 10, nucleus sensorius nervi trigemini; 11, radix motorius nervi trigemini; 12, nucleus motorius princeps nervi trigemini; 13, radix descendens mesencephalica nervi trigemini; 14, brachium conjunctivum; 15, crossed fibres of nervus trigeminus; 16, lemniscus medialis; 17, formatio reticularis tegmenti; 18, fibræ arcuatæ internæ tegmenti; 19, fibræ arcuatæ internæ ventrales (compact bundle); 20, fasciculus longitudinalis medialis; 21, raphe; 22, cells of the middle line; 23, cells at the dorso-lateral part of the fasciculus longitudinalis medialis (connecting with the cells of the middle line); 24 and 25, nucleus centralis tegmenti, a large aggregation of cells in the tegmentum at the ventral part of the middle line (related to the nuclei pontis); 26, cells of the stratum griseum centrale; 27, scattered large cells of the tegmentum (nucleus magnocellularis diffusus of von Kölliker); 28, nucleus motorius princeps nervi trigemini; 29, cells of the locus cœruleus; 30 nucleus sensorius nervi trigemini; 31, cells of the nucleus olivaris superior; 32, nuclei pontis.

The section is taken at the level of the nuclei of origin of the n. facialis and the n. abducens. In the pars dorsalis pontis the raphe is seen in the middle line. The nucleus n. abducentis is situated close to the floor of the fourth ventricle (14, 18). Running ventralward from the medial side of the nucleus are seen the root fibres of the n. abducens (16); the nucleus n. facialis is present (23); the pars prima of the radix n. facialis exists as a number of scattered fibres radiating dorsalward and medialward (13). The genu internum n. facialis (15) is indicated just medial to the nucleus n. abducentis, the pars secunda of the radix n. facialis passing obliquely ventralward and lateralward at 11. A portion of the nucleus n. vestibuli is shown near the floor of the fourth ventricle (12, 20), and lateral from it still some fibres of the radix descendens n. vestibuli (10). At this level the corpus restiforme (9) turns dorsalward to enter the cerebellum. The mass of fibres of the brachium pontis (5) are shown in their relation to the transverse fibres of the pons. Near the raphe, in the formatio reticularis, is a mass of cells, the so-called nucleus reticularis tegmenti of von Bechterew (21). The cells of the substantia gelatinosa (22) are seen chiefly medial to the fibres of the tractus spinalis n. trigemini (8). Running transversely across the pons at the most ventral part of the pars dorsalis pontis are seen the fibres of the corpus trapezoideum, and in between these fibres run lengthwise the fibres of the lemniscus medialis (3). In the lateral part of the corpus trapezoideum is seen the nucleus olivaris superior (6, 24, 25). In the pars basilaris pontis are the fasciculi longitudinales (2), the fibræ pontis profundæ (4) and the fibræ pontis superficiales. In among these transverse and longitudinal bundles are situated the nuclei pontis (27). Some of the cells of this nucleus extend into the tegmental region (26).

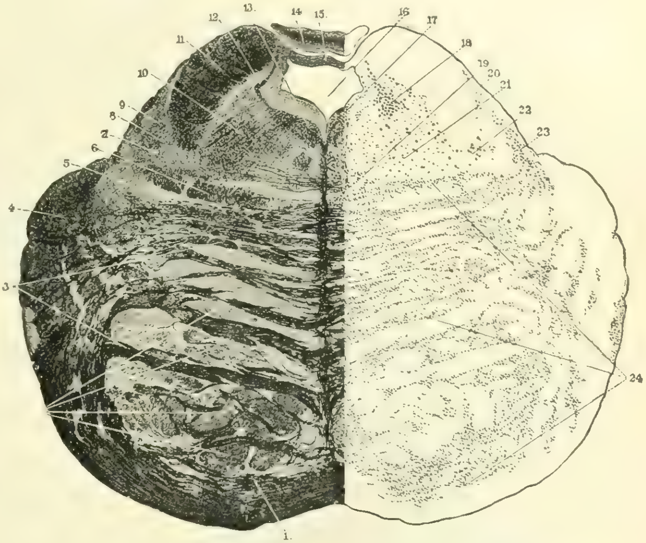

FIG. 952. Transverse Section through the Pons in the Region of the Velum Medullare Anterius in an Adult Human Being. On the left side the fibres have been photographed; on the right side the cell bodies have been drawn in. (After E. Flatau, "Atlas Cerebri Humani," Tab. xiii., Fig. B.) 1, Fibræ pontis superficiales; 2, fasciculi longitudinales pontis; 3, fibræ pontis profundæ; 4, latero-dorsal compact peduncular part of pons; 5, latero-dorsal part of nuclei pontis; 6, lemniscus medialis; 7, nucleus lemnisci lateralis; 8, lemniscus lateralis; 9, continuation of nuclei pontis into lateral portion of tegmentum; 10, formatio reticularis tegmenti; 11, brachium conjunctivum; 12, radix descendens mesencephalica nervi trigemini; 13, fasciculus longitudinalis medialis; 14, lingula; 15, velum medullare anterius; 16, transition from the fossa rhomboidea to the aqueductus cerebri Sylvii; 17, aggregation of cells dorsal from the fasciculus longitudinalis medialis, continuous with the cells of the middle line; 18, cell bodies of the locus cœruleus; 19, continuation of the nuclei pontis into the tegmentum; 20, cells at the ventro-lateral periphery of the brachium conjunctivum; 21, scattered cells in the tegmentum (nucleus reticularis tegmenti of von Bechterew); 22, nucleus lemnisci lateralis; 23, continuation of nuclei pontis into the lateral part of the tegmentum; 24, nuclei pontis.

A section through the pons at the level of the root of the n. trigeminus is illustrated in Fig. 951. Here the pars dorsalis pontis or tegmentum is more sharply differentiated from the pars basilaris pontis than in the previous section. The fourth ventricle is narrowing as the aqueduct of Sylvius is approached. The raphe (21) separates the two halves of the section from each other. Just lateral from the raphe on each side are seen the fibres of the fasciculus longitudinalis medialis. In the floor of the fourth ventricle are seen the cells of the stratum griseum centrale (26). At the lateral angle is a group of pigmented cells of the so-called locus cœruleus (29); the fibres of the corpus restiforme (9) are still visible at this level, and a cross section of the fibres of the superior cerebellar peduncle or brachium conjunctivum (14) is met with. The junction of the n. trigeminus with the pons is shown at 4, the radix n. trigemini at 6. Lateral from it is seen the brachium pontis (5). The sensory portion of the root of the n. trigeminus (8) is distinguishable from the motor portion (11). The sensory nucleus of termination of the n. trigeminus (10) is situated more lateralward than the nucleus motorius princeps n. trigemini (12). The crossed fibres of the trigeminal root are indicated at 15, while the radix descendens mesencephalica n. trigemini is shown at 13. The fibræ arcuatæ internæ (18) are present in the tegmentum of the pons, but are not so much curved as those which were seen in the medulla oblongata. They are more compact in the ventral part of the tegmentum (19). The lemniscus medialis (16) is more laterally placed than in sections lower down. Just dorso-lateral from it is seen the nucleus olivaris superior (7, 31); the nucleus centralis tegmenti (24, 25) at this level makes a large mass of cells near the raphe on each side. In the pars basilaris pontis are seen the fasciculi longitudinales (2), fibræ pontis superficiales (1), the fibræ pontis profundæ (3), and the nuclei pontis (32).

A section taken at a higher level (Fig. 952) shows the beginning of the aqueductus cerebri (16), the root of which is formed by the velum medullare anterius (15). Above this a cross section of the lingula (14) is illustrated. In the lateral portion of the pars dorsalis pontis the large mass of fibres of the brachium conjunctivum (11) is seen. Lateral from the aqueductus cerebri are to be found the fibres of the radix descendens n. trigemini. In the floor of the aqueduct, close to the raphe on each side, is the fasciculus longitudinalis medialis (13); it is separated from the aqueduct by a mass of cells (17). The cells of the locus cœruleus (18) are situated just ventral from the radix descendens n. trigemini. The formatio reticularis tegmenti (10) contains scattered cells of the nucleus reticularis tegmenti (21). Ventro-lateral from the brachium conjunctivum are seen the fibres of the lemniscus lateralis, and among them the cells of the nucleus lemnisci lateralis (22). The lemniscus medialis (6) forms a broad, flat ribbon in the floor of the pars dorsalis pontis. In the pars dorsalis pontis are met with again the fasciculi longitudinales (2), the fibræ pontis superficiales (1), the fibræ pontis profundæ (3), and the nuclei pontis (24).

The next section is taken at the level of decussation of the trochlear nerves of the two sides (Fig. 953). The lumen of the aqueductus cerebri (20) is small and diamond-shaped. In the roof is seen the decussatio nervorum trochlearium, and dorsal from it the lateral part of the velum medullare anterius (16). The radix n. trochlearis before decussation (15) is seen in the central gray matter (21). The locus cœruleus (22) here contains large cells. The comma-shaped cross section of the fasciculus longitudinalis medialis (18) is a striking feature at this level. The lemniscus lateralis (10) is situated lateralward, many of its fibres coming into relation with the nucleus lemnisci lateralis (11). The lemniscus medialis (7) becomes displaced more and more lateralward. The brachium conjunctivum (9, 12) is undergoing decussation (8) at this level; its fibres run through the formatio reticularis tegmenti (17, 25). At the junction of the pars dorsalis with the pars basilaris pontis, near the middle line, is seen the tractus mamillo-peduncularis (Edinger), and lateral from it the bundle from the lemniscus medialis to the basis pedunculi. Close to the middle line, at about this level, are seen cells of the corpus interpedunculare (28). In the pars basilaris pontis the same structures are to be met with as at lower levels.

The next section (see Fig. 954) passes through the midbrain and shows the corpora quadrigemina and the pedunculi cerebri. In the middle line is situated the aqueductus cerebri (24). On each side of the aqueduct dorsalward the section passes through the superior colliculus of the corpora quadrigemina. The amount of the stratum griseum centrale (25, 26) is large in this region. In the superior colliculus passing from the dorsal surface inward can be seen the stratum zonale (20) or superficial white layer, the cappa cinerea (17) or superficial gray layer, the stratum opticum (16) or external grayish-white layer, the middle gray layer (15), the stratum lemnisci (14), the deep white layer (19), and the commissure between the two superior colliculi (21). The cerebral peduncle is divisible into two parts, the tegmentum and

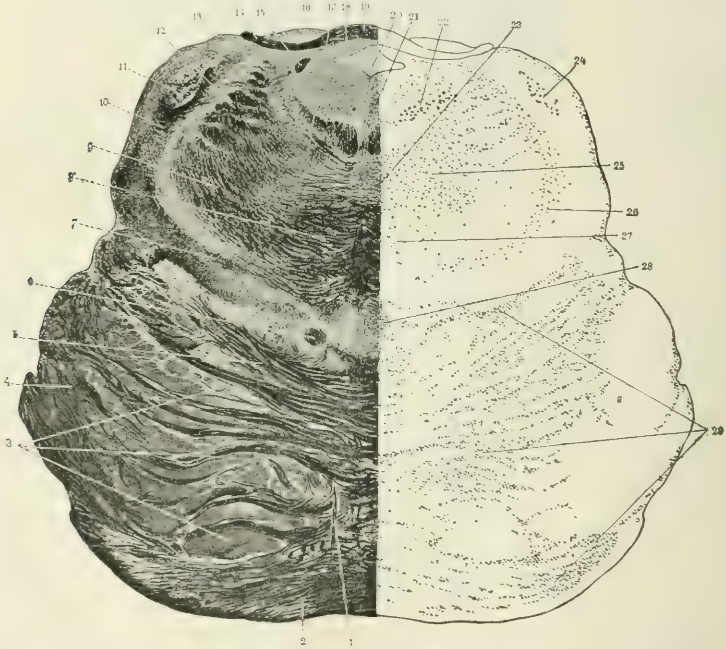

FIG. 953. Transverse Section in the Region of the Proximal Portion of the Pons and of the Decussation of the Trochlear Nerves (Close Behind the Inferior Colliculi of the Corpora Quadrigemina) in an Adult Human Being. (On the left side a photograph of the fibres is represented; on the right side the cell bodies have been drawn in from Nissl preparations. (After E. Flatau, "Atlas Cerebri Humani," Tab. xiv., Berlin, 1899.) 1, Blood-vessel; 2, fibræ pontis superficiales; 3, fasciculi longitudinales pontis; 4, lateral portion of basis pedunculi; 5, fibræ pontis profundæ; 6, tractus mamillo-peduncularis (Edinger) and lateral from it the bundle from the medial lemniscus to the pons (or to the basis pedunculi); 7, lemniscus medialis; 8, decussatio brachii conjunctivi; 9, brachium conjunctivum; 10, lemniscus lateralis; 11, bundles of the lateral lemniscus cut transversely (in the nucleus lemnisci lateralis); 12, brachium conjunctivum; 13, radial transverse bundles of the lemniscus lateralis passing across the radix descendens nervi trigemini; 14, nervus trochlearis after the decussation; 15, nervus trochlearis before the decussation; 16, lateral part of the velum medullare anterius going over into the substance of the tegmentum; 17, formatio reticularis tegmenti; 18, fasciculus longitudinalis medialis; 19, decussatio nervorum trochlearium; 20, aqueductus cerebri Sylvii; 21, cell bodies of the stratum griseum centrale; 22, cells of the locus cœruleus (the dorso-lateral cell bodies belong probably to the radix descendens nervi trigemini); 23, cell bodies of the middle line; 24, nucleus lemnisci lateralis; 25, cell bodies of the formatio reticularis; 26, gray intermediary layer of the formatio reticularis (dorso-medial from the lemniscus); 27, scattered cells in the neighborhood of the decussatio brachii conjunctivi; 28, cells of the corpus interpedunculare (substantia perforata posterior); 29, nuclei pontis.

the basis pedunculi. Between the two is the substantia nigra (3, 39). In the tegmentum, below the stratum griseum centrale, are seen some deep arcuate fibres (18) which represent the continuation of the fibres of the deep white matter of the superior colliculus. The large nucleus ruber (13) is seen at this level in cross section. The formatio reticularis (9) is very highly developed. Lateral from the nucleus ruber are seen the fibres of the lemniscus lateralis, and still more lateralward those of the brachium quadrigeminum superius (10). The corpus geniculatum mediale is shown at 8 and 33, while the pulvinar of the thalamus is seen at 11 and 32. Entering the corpus geniculatum laterale and the pulvinar is the tractus opticus (7). The fibres of the lemniscus medialis (6) are seen between the nucleus ruber and the substantia nigra. Near the middle line the fasciculus longitudinalis medialis (22) is met with in cross section. Just dorsal to it is the nucleus n. oculomotorii (36, 37). The root fibres of this nerve (2) are shown passing ventralward to the interpeduncular space. The ventral tegmental decussation of Forel is visible at 1.

The basis pedunculi consists of a compact mass of fibres that is sometimes known as the pes pedunculi cerebri. Through it run the fibres of the pyramidal tract, those of the frontal cerebro-cortico-pontal path, and those of the temporal cerebro-cortico-pontal path.

One of the most satisfactory methods of studying the structure of the medulla, pons, and midbrain is by wax reconstruction from serial sections. The model constructed by Miss Florence Sabin from specimens prepared by Dr. John Hewetson is of especial value inasmuch as it gives ideas in three dimensions of the form relations of this part of the brain.* The model and its parts are depicted in Plate A and Figs. 955–962. The model as a whole is well shown in Plate A and Fig. 955. In Plate A the model is viewed from the lateral surface and its relations to the spinal cord and cerebellum and the third ventricle are illustrated. In Fig. 955 it is viewed from the dorsal surface and the fourth ventricle is seen to be an important guide. A large central fibre mass containing the medial, lateral, and superior lemnisci has formed the basis of the model. This central fibre mass is divided into two parts by a cross bar of fibres, the corpus trapezoideum. The distal part consists of a thin sheet of fibres extending the whole length of the medulla and reaching almost from the dorsal to the ventral surface (Fig. 958); Miss Sabin calls it the medulla sheet. The proximal part is divisible into three subdivisions, the ventral division (lemniscus medialis), a dorsal division (fasciculus longitudinalis medialis), and a middle portion (formatio reticularis). The medulla sheet corresponds dorsalward to the upward continuation of the ground bundles of the spinal cord, ventralward to the stratum interolivare lemnisci.

The ventral fibres of the proximal subdivision of the central fibre mass are divisible into: (1) a horizontal pontal sheet and (2) a vertical midbrain sheet. The lateral portion of the pontal sheet contains the bulk of its fibres. It is the lemniscus medialis on its way to the diencephalon. By gradual rotation the horizontal pontal sheet becomes the obliquely vertical midbrain sheet (Fig. 959). In the centre of the midbrain sheet runs the lemniscus medialis. Ventral to it is a part of the capsule of the nucleus ruber, while dorsal to it are the fibres of the lemniscus superior or Obereschleife of the Germans.

The dorsal portion of the proximal subdivision of the central fibre mass is the fasciculus longitudinalis medialis and is obviously the continuation of the dorsal part of the medulla sheet (Figs. 957 and 960). It follows the course of the floor of the ventricle. The bundles of the two sides form a trough at the beginning of the midbrain (Fig. 956). In the sides of the trough are shallow depressions, three on the right side and two on the left. They correspond in position to the nuclei of the oculo-

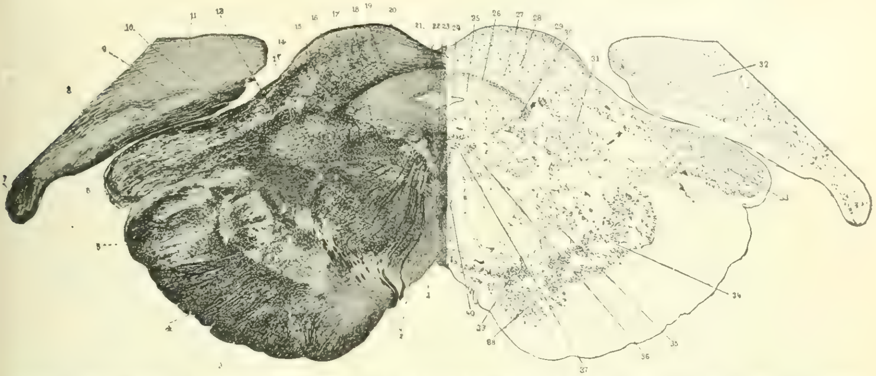

FIG. 954.—Transverse Section through the Superior Colliculi of the Corpora Quadrigemina and the Pedunculi Cerebri in an Adult Human Being. On the left side the fibres have been photographed; on the right the cells have been drawn in. (After E. Flatau, "Atlas Cerebri Humani," Berlin, 1899, Tab. xv.) 1, Ventral tegmental decussation of Forel; 2, radix nervi oculomotorii; 3, substantia nigra Soemmeringi; 4, basis pedunculi; 5, longitudinal bundles in the lateral part of the substantia nigra; 6, lemniscus medialis; 7, tractus opticus entering the corpus geniculatum laterale; 8, corpus geniculatum mediale; 9, formatio reticularis tegmenti; 10, brachium quadrigeminum superius; 11, thalamus; 12, lemniscus lateralis; 13, nucleus ruber (proximal part); 14, part of lemniscus medialis; 15, middle gray layer; 16, stratum opticum (external grayish-white layer); 17, cappa cinerea (superficial gray layer of superior colliculus); 18, deep arcuate fibres; 19, deep white layer of superior colliculus; 20, stratum zonale (superficial white layer of superior colliculus); 21, commissure of superior colliculi; 22, fasciculus longitudinalis medialis; 23, dorsal tegmental decussation of Meynert; 24, aqueductus cerebri Sylvii; 25, cell bodies in stratum griseum centrale; 26, aggregation of cells in peripheral part of stratum griseum centrale; 27, cell bodies of internal grayish-white layer; 28, cell bodies of middle gray layer with scattered large multipolar cells; 29, cell bodies of the cappa cinerea; 30, cell bodies of the radix descendens nervi trigemini; 31, aggregation of cell bodies in latero-dorsal part of tegmentum; 32, cells of distal part of thalamus (pulvinar); 33, cell bodies of corpus geniculatum mediale; 34, cell bodies of substantia nigra; 35, cell bodies of proximal part of nucleus ruber; 36, nucleus nervi oculomotorii extending ventralward into the region of the fasciculus longitudinalis medialis; 37, nucleus nervus oculomotorii; 38, most proximal remnant of nuclei pontis; 39, cell bodies of substantia nigra; 40, cell bodies of the middle line.

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* Sabin, Florence R.: "A Model of the Medulla Oblongata, Pons, and Midbrain of a New-Born Babe." Contributions to the Science of Medicine, dedicated by his pupils to William Henry Welch on the Twenty-fifth Anniversary of his Doctorate. The Johns Hopkins Press, Baltimore, 1900, pp. 925–1045.

motor and trochlear nerves (Fig. 960). The space cerebralward from these depressions left in the wall corresponds to the region of exit of the main mass of fibres of the root of the oculomotor nerve (Fig. 960). Proximal from this space is a long groove which opens out into the proximal capsule of the nucleus ruber. The groove contains the nucleus of Darkschewitsch and marks the junction of three different masses of fibres: (1) the fasciculus longitudinalis medialis; (2) the commissura posterior, and (3) the capsule of the nucleus ruber. The sides of the trough formed by the fasciculi longitudinales mediales of the sides are related in the model to a large hollow shell which occupies the centre of the dorsal part of the midbrain. It represents the stratum album profundum. The relations of the fasciculus longitudinalis medialis to the nuclei of the motor cerebral nerves is striking. It is in intimate relation with the nuclei of the n. hypoglossus, n. abducens, n. trochlearis, and, n. oculomotorius.

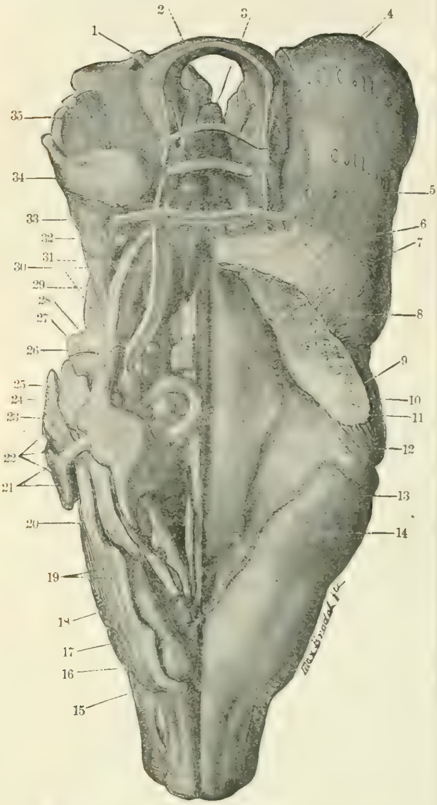

FIG. 955. View of the Model from the Dorsal Surface. The right side of the view shows the surface form, the left the structures of the model. The position of these structures can be related to the dorsal funiculi of the spinal cord, the fourth ventricle, and the inferior and superior colliculi. 1, Fasciculus retroflexus (Meynerti); 2, stratum album profundum; 3, nucleus n. oculomotorii; 4, commissuræ nuclei colliculi inferioris; 5, nucleus n. trochlearis; 6, substantia ferruginæ; 7, ventriculus quartus; 8, brachium conjunctivum; 9, corpus restiforme; 10, radix n. facialis (genu internum); 11, nucleus n. abducentis; 12, fasciculus longitudinalis medialis; 13, nucleus olivaris inferior; 14, nucleus n. hypoglossi; 15, fasciculus gracilis; 16, nucleus funiculi gracilis; 17, fasciculus cuneatus; 18, nuclei funiculi cuneati; 19, tractus solitarius et nucleus alæ cinereæ; 20, corpus restiforme; 21, nucleus n. cochleæ dorsalis; 22, nucleus et radix n. vestibuli; 23, corpus restiforme; 24, nucleus n. vestibuli lateralis; 25, nucleus n. trigemini (sens.); 26, nucleus motorius princeps n. trigemini; 27, radix n. trigemini (sens.); 28, radix n. trigemini (mot.): 29, locus cœruleus; 30, radix descendens n. trigemini; 31, brachium conjunctivum; 32, *a*; 33, radix n. trochlearis; 34, nucleus colliculi inferioris; 35, lemniscus medialis.

Nucleus et radix n. vestibuli: The ascending root is marked by the most proximal of the three lines on the figure; the descending by the most distal line, while the nucleus n. vestibuli medialis is indicated by the middle of the three lines. The nucleus n. vestibuli superior is continuous with the medial nucleus and lies opposite the ascending root. The nucleus n. vestibuli lateralis consists of two parts, one between the corpus restiforme and the ascending root, the other in the notch between the medial and superior nuclei.

Nucleus n. cochleæ dorsalis: The more proximal of the two lines points to the striæ acusticæ. (After Sabin, F. R.)

The middle portion of the proximal subdivision of the central fibre mass corresponds to a part of the formatio reticularis alba. The relations of the nuclei of the cerebral nerves to the central fibre mass are interesting. In Fig. 957 of the model can be seen the trough which contains the ventral column of gray matter of the spinal cord, opening out on to the medulla sheet. From this point two separate groups of nuclei belonging to the cerebral nerves can be traced: a median motor group, and a lateral group containing both motor and sensory nuclei. The median motor group includes the nucleus n. hypoglossi, the nucleus n. abducentis, the nucleus n. trochlearis, and the nucleus n. oculomotorii. The lateral group, lying near the formatio reticularis, can be subdivided into a ventral motor group and a dorsal sensory group. The motor group includes the nucleus n. accessorius of the motor nuclei of the n. glosso-pharyngeus, n. vagi, n. facialis, and n. trigeminus. The sensory group includes the nuclei of termination of the sensory portions of the n. glosso-pharyngeus, n. vagus, n. intermedius, and n. trigeminus, together with all the nuclei of the cochlear and vestibular nerves.

The corpus restiforme and brachium conjunctivum are well illustrated in the model. The corpus restiforme is made up at this stage chiefly of the direct cerebellar tract from the lateral funiculus from the spinal cord and the dorsal external arcuate fibres from the dorsal funiculi. The fibræ olivo-cerebellares are non-medullated at this stage. The relation of the corpus restiforme to the spinal cord, as well as its position with reference to the cerebellum and to the other cerebellar peduncles, is shown in Plate A.

The brachium conjunctivum or superior cerebellar peduncle is illustrated in Plate A, and Figs. 955, 956, and 960. The part of it which forms the commissure between the superior nuclei of the vestibular nerve is well shown (Fig. 960).

A number of facts concerning the cerebral nerves and their nuclei are made apparent in the model. The nuclei of the median group all lie near the middle line just ventral to the central canal and are closely related to the fasciculus longitudinalis medialis (Fig. 957). The nuclei of the n. hypoglossus and n. abducens are very near the dorsal surface, while the nuclei of the n. trochlearis and n. oculomotorius are farther ventral inasmuch as they lie on the midbrain curve. The nerve fibres from all the nuclei of the groups except those of the root of the n. trochlearis pass ventralward to the surface near the middle line. The root of the n. trochlearis takes an anomalous course since it passes dorsalward, decussates in the velum, and leaves the brain on the dorsal surface of the isthmus of the rhombencephalon. The motor nuclei of the lateral group lie in the formatio reticularis at a considerable distance from the middle line and at a level ventral from the central canal. The root fibres from these nuclei, with the exception of those of the n. trigeminus, do not follow a direct course toward the surface of the central nervous system. The root fibres of all four nerves take their exit at the lateral sulcus.

The sensory nuclei of the entire region belong to the lateral group, and their root fibres enter without exception on the lateral surface (Plate A and Fig. 956). From

PLATE A.

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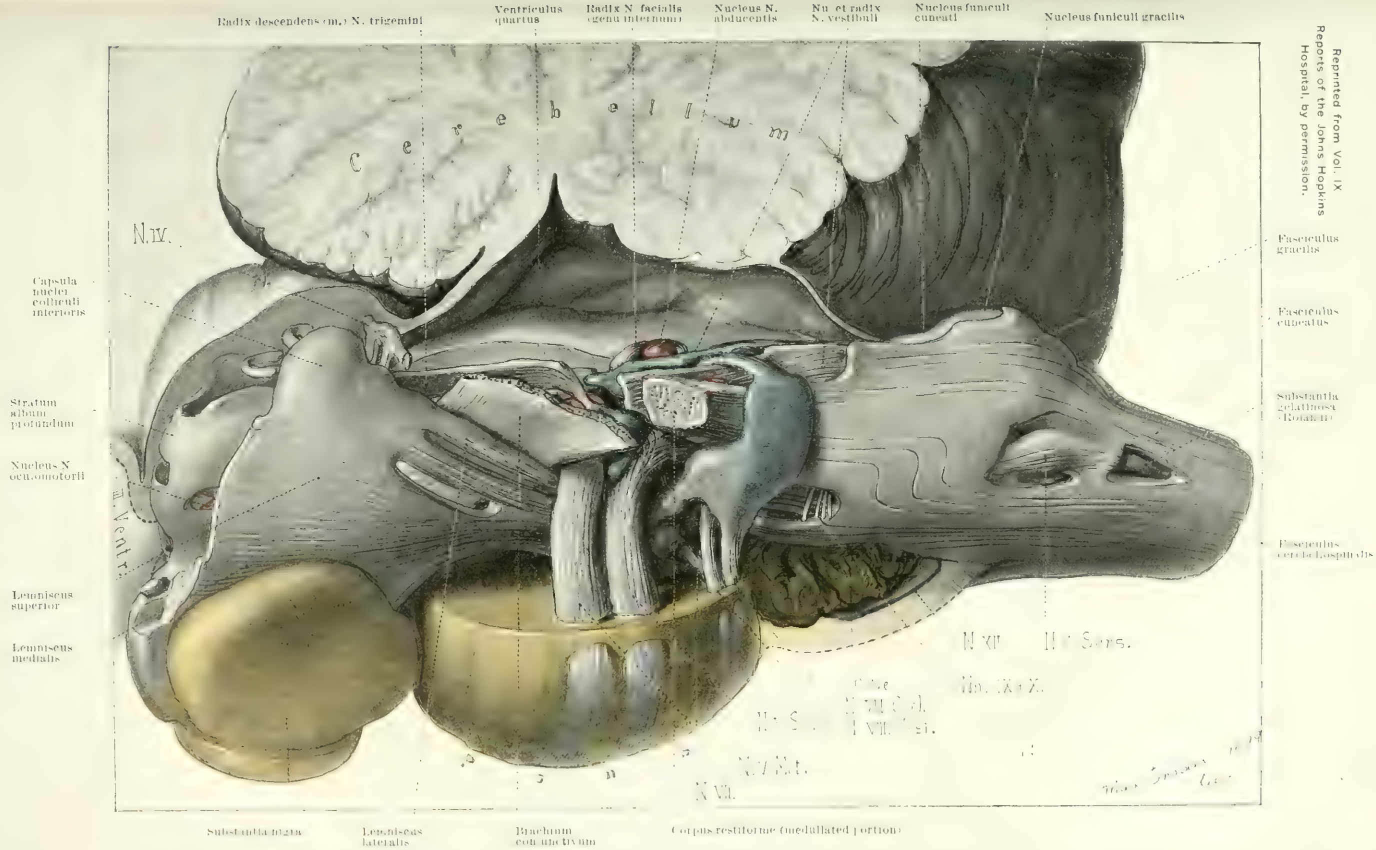

A WAX PLATE RECONSTRUCTION OF THE MEDULLA, PONS AND MIDBRAIN OF THE NEWBORN BABE. MOTOR NUCLEI RED; SENSORY NUCLEI BLUE; OTHER NUCLEI YELLOW.
(After Florence R. Sabin, Welch Volume of Contributions to Medical Science, 1900.)

what we know of the relation of sensory fibres to motor fibres in the spinal cord, it is not surprising that the sensory nuclei tend to occupy a position farther dorsalward than the motor nuclei of the lateral group.

The n. hypoglossus arises from the nucleus n. hypoglossi which is seen to be long, and its dorsal border conforms to the cervical curve. The nucleus extends more than one-half the length of the medulla, corresponding in general to the extent of the nucleus olivaris inferior. The root fibres leave the nucleus from its ventral border and have their superficial origin between the olive and the pyramid. The nucleus n. abducentis is well shown in Figs. 957 and 958. It lies in the distal part of the pons just below the floor of the fourth ventricle and just lateral from the fasciculus longitudinalis medialis. Its relations to the knee of the facial nerve are beautifully shown in three dimensions. The root fibres of the nerve leave the nucleus at its ventro-medial border and pass ventralward and slightly spinalward, emerging between the pons and the medulla near the middle line. The root fibres of the n. abducens pass through the trapezoid body.

The nuclei of the trochlear and oculomotor nerves are illustrated in Plate A and Figs. 955 and 956. These nuclei lie in a trough formed by the fasciculus longitudinalis medialis on its midbrain curve. The nucleus of the trochlear nerve is distally and dorsally situated on the curve, lying as it does in the proximal part of the colliculus inferior. There is a lack of symmetry in the nuclei of the two sides, as the mass of cell bodies is single on the left side and double on the right. The volumes of the cell masses of the two sides are, however, about equal. The root fibres leave the lateral and dorsal border of the nucleus and pass at first lateralward in scattered bundles. They then turn dorsalward and slightly spinalward. In this dorsal course the fibres of the root bundles are collected into from two to four compact bundles, lying in the central gray matter just inside the stratum profundum album. The decussation dorsal to the central canal is well illustrated in Fig. 955.

The nucleus of the n. oculomotorius is seen in Fig. 955 to consist of a long mass of cells lying in the trough before mentioned. The nucleus as a whole lies farther ventralward than does the nucleus n. trochlearis. The nucleus is placed obliquely to a horizontal plane so that the distal end is situated farther dorsalward than the proximal end. The nuclei of the two sides lie so close together that they have been modelled as a single mass, which consists of two lateral parts which are fused together in their ventral portions so as to make a gutter in which lies the median nucleus. The whole mass has the shape of a triangular prism with the apex pointing ventralward and the base dorsalward. The course of the root fibres leaving the nucleus is best seen in Fig. 956. The root bundle runs ventralward between the brachium conjunctivum and the red nucleus to the superficial origin in the fossa interpeduncularis.

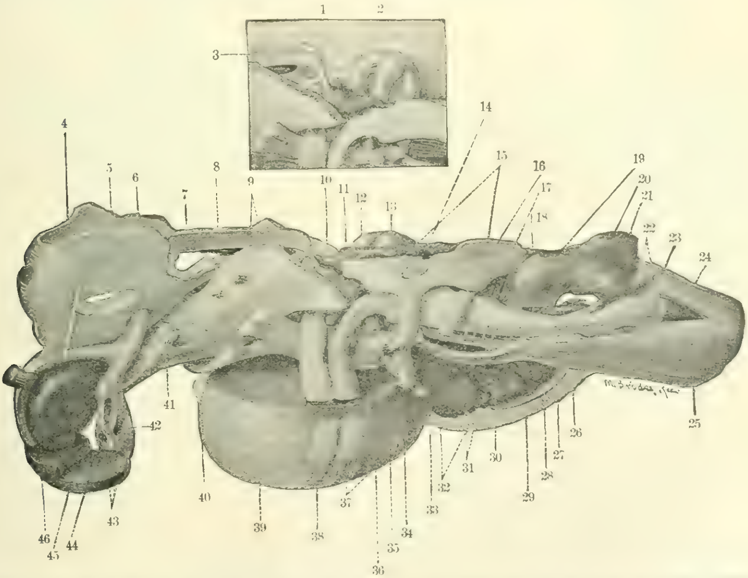

FIG. 956.—View of the Model from the Lateral Aspect. After removing from Plate A the following structures: the corpus restiforme, the substantia nigra, and the medial, lateral, and superior lemnisci. The view is designed to show (1) the sensory nerves and their nuclei, and (2) the midbrain. The nuclei of the dorsal funiculi represent a way station for the sensory fibres from the spinal cord; the sensory cerebral nerves are represented by the nuclei nervi glosso-pharyngei, vagi, vestibuli, et trigemini. These include all of the sensory nerves of the region of the model, except the n. cochleæ, which was removed with the corpus restiforme. 1, Nucleus motorius princeps n. trigemini; 2, nucleus n. trigemini (sensory); 3, radix descendens (m.) n. trigemini; 4, stratum album profundum; 5, nucleus n. oculomotorii; 6, radix n. oculomotorii; 7, radix descendens (m.) n. trigemini; 8, a; 9, brachium conjunctivum; 10, fasciculus longitudinalis medialis; 11, nucleus n. vestibuli superior; 12, radix n. facialis (genu internum); 13, nucleus n. abducentis; 14, nucleus n. vestibuli lateralis; 15, radix descendens et ascendens n. vestibuli; 16, fibres to tractus solitarius; 17, radices n. IX. and X.; 18, tractus solitarius; 19, nucleus funiculi cuneati; 20, nucleus funiculi gracilis; 21, nucleus funiculi cuneati lateralis; 22, fasciculi graciles; 23, fasciculus cuneatus; 24, substantia gelatinosa (Rolandi); 25, fasciculus cerebellospinalis; 26, fibræ arcuatæ internæ (distal bundle); 27, substantia gelatinosa (Rolandi); 28, fasciculus cerebro-spinalis; 29, radix n. hypoglossi; 30, nucleus olivaris inferior; 31, radices n. IX. and X.; 32, tract from Deiters' nucleus to spinal cord; 33, fasciculus lateralis; 34, radix n. vestibuli; 35, radix n. facialis; 36, corpus trapezoideum; 37, radix n. trigemini (sens.); 38, radix n. trigemini (mot.); 39, lemniscus lateralis; 40, lemniscus medialis; 41, fibres to decussatio tegmenti dorsalis; 42, radix n. oculomotorii; 43, nucleus columnaris; 44, nucleus capsulæ lateralis nuclei rubri; 45, lectus substantiæ nigræ; 46, nucleus ruber.

Radix n. trigemini (sens.): The proximal line runs to the root bundle, the distal to the tractus spinalis n. trigemini. (After Sabin, F. R.)

As to the n. accessorius, only the extreme proximal part of the spinal portion is shown in the model. The so-called vagus portion of the nerve is not illustrated. The root fibres of the nerve, instead of passing directly from the cell bodies of origin to the lateral groove, pass dorsalward and then turn ventralward and lateralward toward the superficial origin, thus forming what Miss Sabin refers to as a pars prima and a pars secunda of the root.

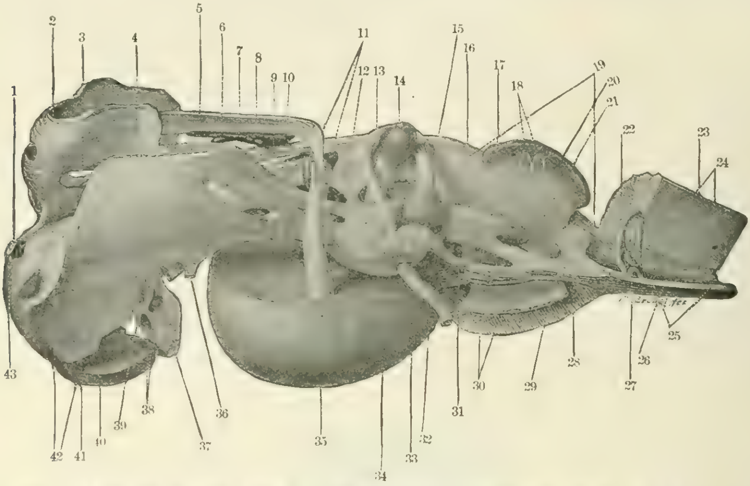

FIG. 957.—View of the Model from the Lateral Aspect. The sensory nerves of Fig. 956 have been removed and all of the motor cerebral nerves except the n. trochlearis are now shown. 1, Fasciculus retroflexus (Meynerti); 2, capsula dorsalis nuclei rubri; 3, nucleus n. oculomotorii; 5, radix descendens (m.) n. trigemini; 6, lemniscus medialis; 7, locus cœruleus; 8, lemniscus lateralis; 9, fasciculus longitudinalis medialis; 10, formatio reticularis alba; 11, nucleus motorius princeps n. trigemini; 12, formatio reticularis alba; 13, radix n. facialis (genu internum); 14, nucleus n. abducentis; 15, nucleus n. facialis; 16, tract from Deiters' nucleus to funiculus lateralis; 17, nucleus ambiguus; 18, radices n. IX. and X. (mot.); 19, fasciculus longitudinalis medialis; 20, nucleus n. hypoglossi; 21, radix n. hypoglossi; 22, radix n. accessorii; 23, fasciculus gracilis; 24, canalis centralis; 25, position of columna ventralis; 26, fasciculus ventralis proprius; 27, fasciculus cerebello-spinalis; 28, fasciculus cerebello-spinalis; 29, fasciculus lateralis; 30, radix n. hypoglossi; 31, nucleus olivaris accessorius medialis; 32, nucleus olivaris superior; 33, radix n. facialis, pars secunda; 34, corpus trapezoideum; 35, radix n. trigemini (mot.); 36, lemniscus medialis to substantia nigra; 37, radix n. oculomotorii; 38, nucleus columnaris; 39, nucleus capsulæ lateralis nuclei rubri; 40, lectus substantiæ nigræ; 41, capsula lateralis nuclei rubri; 42, lemniscus medialis; 43, capsula superior nuclei rubri. (After Sabin, F. R.)

The nucleus ambiguus or motor nucleus of origin of the n. glosso-pharyngeus and the n. vagus is diagrammatically represented in Fig. 957. It lies in the formatio reticularis, dorso-lateral to the dorsal accessory olive and lateral from the tract from Deiters' nucleus to the spinal cord. It is on about the same horizontal level as the nucleus n. facialis. The root fibres are divided by Miss Sabin into a pars prima and a pars secunda. In the pars prima they pass medianward and dorsalward toward the floor of the fourth ventricle. Then the pars secunda begins, the fibres turning sharply to pass ventralward and lateralward, where they follow the same course as do the entering sensory fibres of the same nerve. The root fibres plunge through the tractus spinalis n. trigemini.

The nucleus n. facialis, situated in the dorsal part of the pons just dorsal to the level of the corpus trapezoideum, is seen in Fig. 957. It is a compact oval mass of cells having its long axis parallel to the long axis of the pons. The illustration in three dimensions of the root fibres, including the pars prima, the genu internum, and the pars secunda, represents one of the most satisfactory features of the model. The motor part of the n. trigeminus is shown in Fig. 962, and the entire nerve is well illustrated

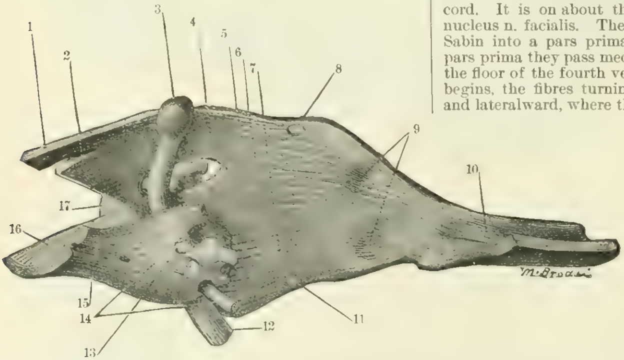

FIG. 958.—View of the Lateral Surface of the Medulla Sheet. The view can be related to Plate A and Figs. 955 and 956 by the position of the nucleus n. abducentis. 1, Fasciculus longitudinalis medialis; 2, formatio reticularis alba; 3, nucleus n. abducentis; 4, position of nucleus centralis inferior; 5, fasciculus longitudinalis medialis; 6, formatio reticularis alba; 7, lemniscus medialis; 8, nucleus of Roller; 9, position of part of nucleus accessorius medialis; 10, position of columna ventralis in fasciculus ventro-lateralis (1); 11, nucleus olivarius superior; 12, radix n. abducentis; 13, corpus trapezoideum; 14, radix n. facialis, pars secunda; 15, lemniscus lateralis; 16, lemniscus medialis; 17, corpus trapezoideum. (After Sabin, F. R.)

in Fig. 956. The nucleus motorius princeps n. trigemini lies in the middle of the pons, just proximal to the transverse part of the knee of the facial nerve. The distal end lies opposite the proximal end of the nucleus olivaris superior. The radix descendens mesencephalica n. trigemini is seen in the model starting at the distal border of the stratum album profundum and traversing the pons as a narrow bundle parallel to the raphe. Its relation to the locus cœruleus is obvious. The decussating fibres pertaining to the n. trigeminus are shown in Fig. 955.

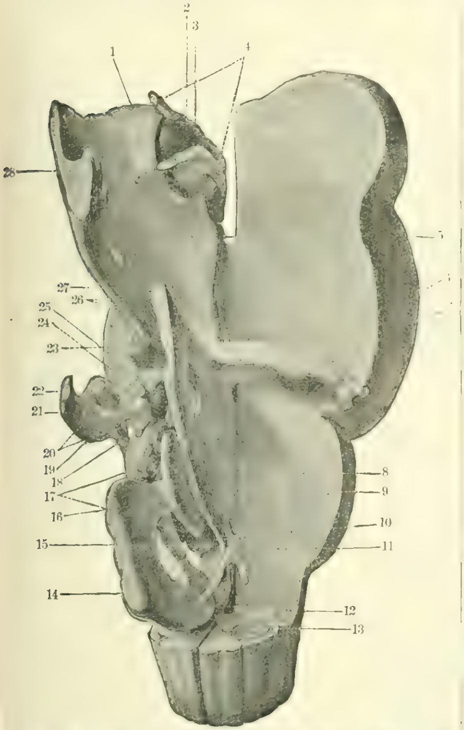

FIG. 959. View of the Model from a Dorso-Median Aspect. This view is designed to show the central fibre mass, that is, the medulla, pontal and midbrain sheets, together with the corpus trapezoideum. 1, Capsula superior nuclei rubri; 2, radix n. oculomotorii; 3, nucleus ruber; 4, fasciculus retroflexus (Meynerti); 5, lemniscus medialis; 6, corpus trapezoideum; 7, nucleus olivaris superior; 8, stratum interolivare lemnisci; 9, nucleus n. hypoglossi; 10, nucleus olivaris accessorius medialis; 11, decussatio lemniscorum; 12, canalis centralis; 13, substantia gelatinosa (Rolandi); 14, nucleus funiculi gracilis; 15, fasciculus cuneatus to formatio reticularis; 16, nucleus funiculi cuneati; 17, nucleus olivaris inferior; 18, radix n. cochleæ; 19, corpus trapezoideum; 20, radix n. vestibuli; 21, nucleus n. cochleæ dorsalis; 22, striæ acusticæ; 23, nucleus n. abducentis; 24, radix n. facialis; 25, nucleus olivaris superior; 26, formatio reticularis alba; 27, fasciculus longitudinalis medialis; 28, lemniscus lateralis.

a, Fibres running from lemniscus lateralis to the brachium conjunctivum. (After Sabin, F. R.)

As regards the sensory nuclei in the model, those connected with the n. glosso-pharyngeus and n. vagus may first be referred to. They include the nucleus alæ cinereæ and the nucleus tractus solitarii. These are well illustrated in Figs. 955 and 956. The mass of cell bodies situated at the distal end of the tractus solitarius, shown in Fig. 955, possibly corresponds to the commissural nucleus of Ramón y Cajal.

The sensory nucleus of the n. trigeminus corrresponds to the substantia gelatinosa. In Fig. 956 the sensory fibres of the n. trigeminus are seen to enter the lateral surface of the pons just distal to the motor bundle. The fibres form a compact mass, which extends dorsalward past the lemniscus lateralis into the region of the pars dorsalis pontis. The bundle bifurcates into a Y, corresponding to the Y-shaped bifurcation of its constituent fibres. Into the notch of the Y fits the upper end of the sensory nucleus. The lateral and longer arm of the Y forms the tractus spinalis n. trigemini. The medial and shorter arm of the Y passes dorsalward just medial to the sensory nucleus. The tractus spinalis n. trigemini extends from the middle of the pons to the upper part of the cervical spinal cord. It lies medial to the cochlear nuclei but lateral from the nuclei of the dorsal funiculi. For details with regard to the sensory nucleus of the trigeminal nerve and the tractus spinalis n. trigemini, Miss Sabin's article may be consulted.

The various nuclei connected with the n. vestibuli are depicted in three dimensions in the model. The root fibres of the vestibular nerve, on entering the central nervous system, bifurcate into short ascending limbs and long descending limbs. The bundle of descending limbs is known as the radix descendens n. vestibuli. There are four nuclei, namely: (1) the nucleus n. vestibuli medialis; (2) the nucleus n. vestibuli radicis descendentis, which is directly continuous with (1); (3) the nucleus n.

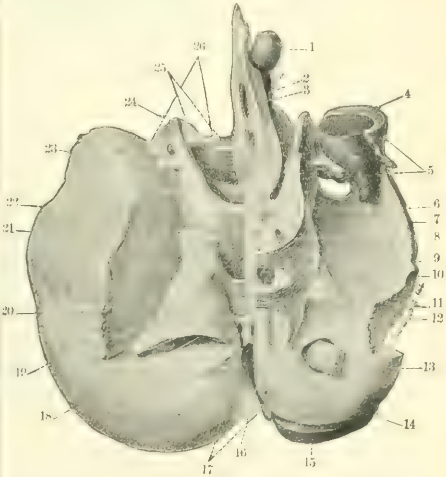

FIG. 960.—View of the Midbrain from the Superior or Cerebral Aspect. This view can be understood by comparing it with Plate A and Figs. 956 and 957, which show the stratum profundum album, the lemniscus superior, and the capsula nuclei rubri from the lateral aspect. 1, Nucleus n. abducentis; 2, fasciculus longitudinalis medialis; 3, nucleus reticularis tegmenti; 4, nucleus colliculi inferioris; 5, capsula nuclei colliculi inferioris; 6, position of nucleus n. trochlearis; 7, lemniscus superior; 8, γ; 9, position of nucleus n. oculomotorii; 10, stratum album profundum; 11, lemniscus medialis; 12, commissura posterior; 13, fasciculus retroflexus (Meynerti); 14, capsula superior nuclei rubri; 15, lectus nuclei rubri; 16, nucleus fasciculi longitudinalis medialis; 17, fasciculus longitudinalis medialis; 18, decussatio tegmenti ventralis; 19, decussatio tegmenti dorsalis; 20, capsula dorsalis nuclei rubri; 21, decussatio tegmenti dorsalis: 22, brachium conjunctivum: 23, α; 24, brachium conjunctivum (dorsalis bundle); 25, corpus trapezoideum and nucleus olivaris superior; 26, commissure between Bechterew's nuclei.

γ is a space in the model, in the stratum profundum album, where fibres of the formatio reticularis alba are related to the substantia centralis grisea. (After Sabin, F. R.)

vestibuli superior or nucleus of von Bechterew, and (4) the nucleus n. vestibuli lateralis or nucleus of Deiters. The last-mentioned nucleus is divisible into two parts, one part lying lateral to the root bundle of the vestibular nerve and the other part lying in an angle between the superior and medial nuclei of the vestibular nerve. The model illustrates further a set of internal arcuate fibres passing from the medial nucleus to the raphe, a commissure between the superior vestibular nuclei off the two sides, a tract from Deiters' nucleus to the spinal cord, and two sets of fibres relating the vestibular area with the cerebellum.

Connected with the n. cochleæ near its entrance are two definite nuclei of termination, namely, the nucleus n. cochleæ ventralis and the nucleus n. cochleæ dorsalis (Plate A). The relation of the ventral cochlear nucleus to the corpus trapezoideum is shown in Figs. 959 and 960.

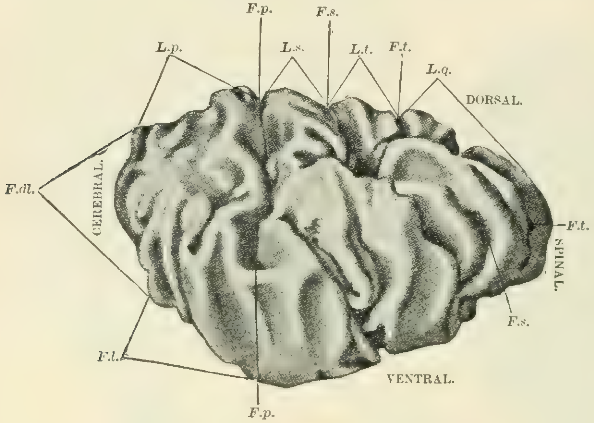

FIG. 961.

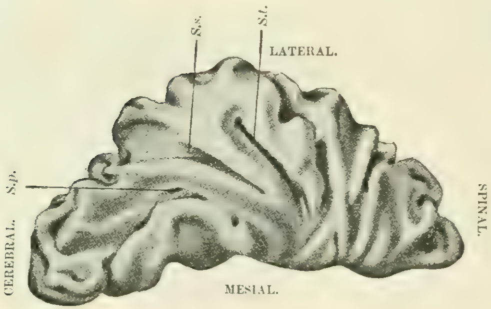

FIG. 962.

FIGS. 961 AND 962.—FIG. 961.—View of the Dorso-Lateral and Lateral Surfaces of the Nucleus Olivaris Inferior. *f.dl.*, Facies dorso-lateralis; *f.l.*, facies lateralis; *f.p.*, fissura prima; *f.s.*, fissura secunda; *f.t.*, fissura tertia; *f.q.*, fissura quarta; *l.p.*, lobus primus; *l.s.*, lobus secundus; *l.t.*, lobus tertius; *l.q.*, lobus quartus.
FIG. 962.—View of the Ventral Surface of the Nucleus Olivaris Superior. *s.p.*, Sulcus primus; *s.s.*, sulcus secundus; *s.t.*, sulcus tertius. (After Sabin, F. R.)

A surprising feature of the model is the appearance presented by the nucleus olivaris inferior (Figs. 961, 962). Sections through the medulla have long taught us that the gray matter of the olive forms a hollow shell with a wrinkled wall, but the method of reconstruction indicates that the olive has a constant and definite shape, its surface being marked by gyri and sulci as definitely as that of the cerebral cortex. Miss Sabin describes the lateral surface as presenting four lobes. The first or proximal lobe is the largest; it is subdivided in the dorsal portion by two or three groups or sulci. It contains three gyri. The second and third lobes each consist of a single convolution or gyrus; the fourth lobe is the smallest of all, and consists like the second and third of a single gyrus.

In the midbrain the main bundles of fibres have been modelled as well as the nucleus ruber and its capsule, the fasciculus retroflexus of Meynert, the various decussations of the tegmentum, the stratum album profundum, the substantia centralis grisea, and the substantia nigra.

Passing now to the histology and microscopic anatomy of the prosencephalon, we may begin by a description of some sections which pass through the hypothalamus and the thalamencephalon.

In Fig. 963, which represents a transverse section through the human brain at the level of the decussatio brachii conjunctivi, the positions of the lemniscus superior and of the main portions of the lemniscus medialis are outlined. Lateral and dorsal from the lemniscus superior is seen the brachium quadrigeminum inferius.

In a section higher up (Fig. 964), in addition to structures met with in sections lower down, some of the nuclei of the thalami are seen, the nucleus ventralis lateralis thalami and

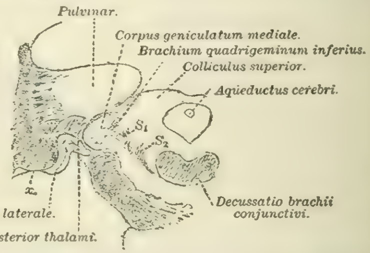
Pulvinar.
Corpus geniculatum mediale.
Brachium quadrigeminum inferius.
Colliculus superior.
Aqüeductus cerebri.
S₁
S₂
x
Decussatio brachii conjunctivi.
Corpus geniculatum laterale.
Nucleus posterior thalami.

FIG. 963.—Frontal Section through a Normal Human Brain at the Level of the Decussatio Brachii Conjunctivi. (After C. von Monakow, *Arch. f. Psychiat.*, Berlin, Bd. xxvii., 1895. (Taken from "The Nervous System and Its Constituent Neurones," New York, 1900.)

the nucleus posterior thalami. The relation of the lemniscus to the nucleus ventralis lateralis thalami is obvious.

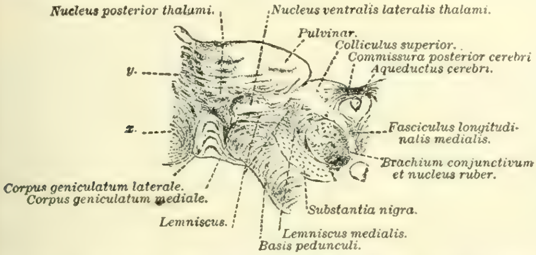
Nucleus posterior thalami.
Nucleus ventralis lateralis thalami.
Pulvinar.
Colliculus superior.
Commissura posterior cerebri
Aqueductus cerebri.
y.
x.
Fasciculus longitudinalis medialis.
Brachium conjunctivum et nucleus ruber.
Corpus geniculatum laterale.
Corpus geniculatum mediale.
Lemniscus.
Substantia nigra.
Lemniscus medialis.
Basis pedunculi.

FIG. 964. Frontal Section through a Normal Human Brain at Level of Upper Extremity of Corpus Geniculatum Mediale. (After C. von Monakow, *Arch. f. Psychiat.*, Berlin, Bd. xxvii., 1895, Taf. ii., Fig. 13. *x*, Lateral white matter of lateral geniculate body; *y*, lateral white matter of pulvinar. (Taken from "The Nervous System and Its Constituent Neurones," New York, 1900.)

More ventrally situated are seen the lateral and medial geniculate bodies.

In a section higher up (Fig. 965) the nucleus hypothalamicus, or Luys' body, is illustrated. In the thalamus are seen the tænia thalami, the nucleus medialis thalami, the lamina medullaris thalami, the nucleus medialis thalami (or *centre median* of Luys), the lamina medullaris medialis, the nucleus ventralis thalami (*b*), the lamina medullaris media, the nucleus ventralis thalami (*a*). Lateral from the latter is seen the capsula interna, and more lateral still the nucleus lentiformis. In the hypothalamus the nucleus hypothalamicus or corpus Luysi is seen just dorsal to the base of the peduncle where it goes over into the capsule.

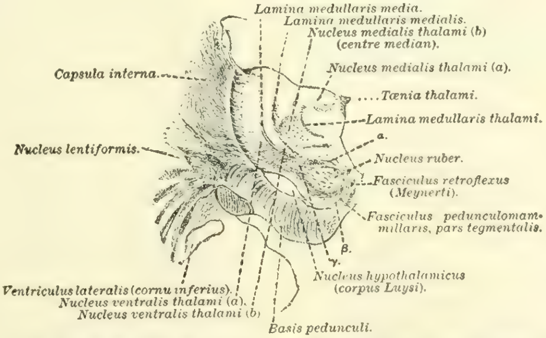
Lamina medullaris media.
Lamina medullaris medialis.
Nucleus medialis thalami (b) (centre median).
Capsula interna.
Nucleus medialis thalami (a).
Tænia thalami.
Lamina medullaris thalami.
a.
Nucleus lentiformis.
Nucleus ruber.
Fasciculus retroflexus (Meynerti).
Fasciculus pedunculomammillaris, pars tegmentalis.
β.
γ.
Nucleus hypothalamicus (corpus Luysi).
Ventriculus lateralis (cornu inferius).
Nucleus ventralis thalami (a).
Nucleus ventralis thalami (b)
Basis pedunculi.

FIG. 965.—Frontal Section through a Normal Human Brain at the Level of the Lower End of the Nucleus Hypothalamicus. After C. von Monakow, *Arch. f. Psychiat.*, Berlin, Bd. xxvii., 1895, Taf. iii., Fig. 20.) *α*, Dorsal white matter of nucleus ruber; *β*, ventral white matter of nucleus ruber; *γ*, lateral white matter of nucleus ruber. (Taken from "The Nervous System and Its Constituent Neurones," New York, 1900.)

A little higher up (Fig. 966), passing from the third ventricle lateralward, are seen the tænia thalami, the lamina medullaris medialis, the nucleus anterior thalami, the nucleus lateralis thalami, and the zona reticularis. Lateral from the latter is seen the capsula interna. The anterior part of the nucleus ventralis thalami is met with in the ventral part of the thalamencephalon. At the ventral extremity of the lamina medullaris medialis, in transverse section, is the fasciculus thalamo-mammillaris (Vicq d'Azyri). In the hypothalamus are seen a part of Forel's field H and the two parts of the ansa lenticularis, namely, the pars dorsalis and the pars ventralis. Ventro-medially situated is the columna fornicis, and most ventral of all in section is the tractus opticus.

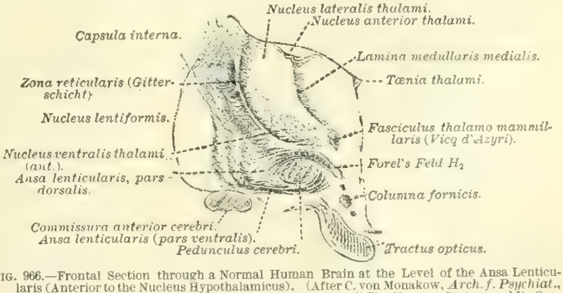
Nucleus lateralis thalami.
Nucleus anterior thalami.
Capsula interna.
Lamina medullaris medialis.
Zona reticularis (Gitterschicht)
Tænia thalami.
Nucleus lentiformis.
Fasciculus thalamo mammillaris (Vicq d'Azyri).
Nucleus ventralis thalami (ant.).
Forel's Feld H₂
Ansa lenticularis, pars dorsalis.
Columna fornicis.
Commissura anterior cerebri.
Ansa lenticularis (pars ventralis).
Pedunculus cerebri.
Tractus opticus.

FIG. 966.—Frontal Section through a Normal Human Brain at the Level of the Ansa Lenticularis (Anterior to the Nucleus Hypothalamicus). (After C. von Monakow, *Arch. f. Psychiat.*, Berlin, Bd. xxvii., 1895, Taf. iii., Fig. 28.) (Taken from "The Nervous System and Its Constituent Neurones," New York, 1900.)

In the next section (Fig. 967) the part cut through corresponds to the most anterior portion of the thalamencephalon. Passing from the middle line lateralward are seen the stratum griseum centrale, the tænia thalami, the nucleus anterior thalami with its ventral capsule, the fasciculus thalamo-mammillaris (Vicq d'Azyri), the nucleus lateralis thalami, and the nucleus ventralis thalami (anterior part). Bounding the thalamus lateralward is the capsula interna of the nucleus lentiformis. The three parts of the nucleus lentiformis are represented, namely, the pars medialis and pars lateralis of the globus pallidus and the putamen. Ventral to the globus pallidus is the commissura anterior cerebri. A portion of the ventral part of the ansa lenticularis is seen in the ventro-medial part of the section.

The histology of the cerebral cortex varies in different parts. At least four layers are usually described (Fig. 968): (1) an external molecular layer; (2) a layer of small pyramidal cells; (3) a layer of large pyramidal cells, and (4) a layer of polymorphous cells. The molecular layer contains a very large number of nerve fibres which run in various directions. They represent for the most part terminals of other cortical cells or of projection or association fibres. The subdivisions of the apical dendrites of the pyramidal cells constitute a large part of this layer. Three types of cells exist here: (1) polygonal cells, (2) spindle-shaped cells, and (3) triangular or stellate cells.

The layer of small pyramidal cells and that of the large pyramidal cells are very characteristic. They contain the pyramidal-shaped perikaryons which are so characteristic of the microscopic picture of the cerebral cortex. Each perikaryon gives off an ascending dendrite known as the chief process and several basilar dendrites. A single axone descends into the white substance.

The layer of polymorphous cells contains also a few pyramidal cells, but a large proportion of cells in this layer are dendraxones (Golgi cells of type II.), and the so-called Martinotti cells which have ascending axones.

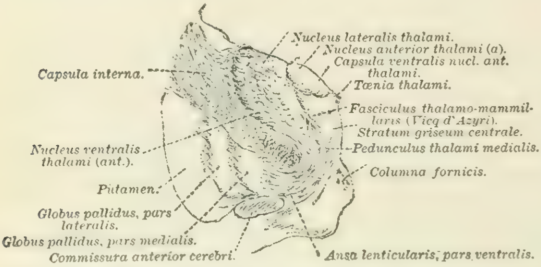
Nucleus lateralis thalami.
Nucleus anterior thalami (a).
Capsula ventralis nucl. ant. thalami.
Tœnia thalami.
Capsula interna.
Fasciculus thalamo-mammillaris (Vicq d'Azyri).
Stratum griseum centrale.
Nucleus ventralis thalami (ant.).
Pedunculus thalami medialis.
Columna fornicis.
Putamen.
Globus pallidus, pars lateralis.
Globus pallidus, pars medialis.
Commissura anterior cerebri.
Ansa lenticularis, pars ventralis.

FIG. 967.—Frontal Section through a Normal Human Brain at Level of Anterior Part of Thalamus. (After C. von Monakow, *Arch. f. Psychiat.*, Berlin, Bd. xxvii., 1895, Taf. iv., Fig. 33. (Taken from "The Nervous System and Its Constituent Neurones," New York, 1900.)

The cortex in the region of the sense centres has a peculiar stamp for each particular sense centre. The structure of the occipital cortex near the calcarine fissure may be cited as an example. A section is shown in Fig. 969. The enormous complexity of the various layers is obvious.

The cortex varies much in appearance, too, in different animals, as will be seen by comparing a section through the human cortex with one from that of the dog and of the mole (*vide supra*).

A schematic section of the cerebellar cortex is shown in Fig. 970. The structures seen in ordinary hæmatoxylin and eosin preparations are illustrated in Fig. 971.

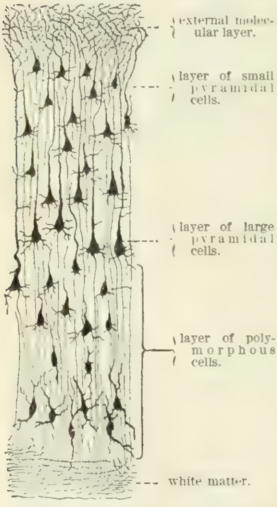
external molecular layer.
layer of small pyramidal cells.
layer of large pyramidal cells.
layer of polymorphous cells.
white matter.

FIG. 968.—Golgi Preparation of the Cerebral Cortex. (After Böhm u. von Davidoff, "Lehrbuch der Histologie," S. 282, Fig. 201.)

Résumé of Conduction Paths in the Brain.—The principal conduction paths in the brain are made up of several sets of superimposed neurones or neurone systems. The conduction paths may be divided into the centripetal or sensory, the centrifugal or motor, and the associative.

The centripetal or sensory conduction paths include those (1) of bodily sensation; (2) of taste; (3) of smell; (4) of sight; (5) of hearing.

The centripetal conduction path of bodily sensation carries the impulses concerned in touch, temperature, pain, muscle sense, and visceral sensations. It consists of a direct conduction path and several roundabout conduction paths. Just which impulses are carried by these various portions of this centripetal conduction path is not known. The most direct conduction path consists in all probability of three sets of superimposed neurones or neurone systems: (1) The peripheral sensory neurones (including the ganglion cells, and their prolongations, of the ganglia on the dorsal roots of the spinal nerves, and the ganglia on the sensory cerebral nerves). (2) A set of neurones extending from the nuclei of termination of the peripheral sensory nerves to the ventro-lateral region of the thalamus (including the nuclei of Goll and Burdach in the medulla and the fibres of the medial lemniscus). (3) A set of neurones, the cell bodies of which are situated in the ventro-lateral part of the thalamus and the axones of which reach to the somæsthetic area of the cerebral cortex, that is, to the central gyri, the feet of the frontal gyri, and the gyrus fornicatus.

The less direct portions of this conduction path concern mainly the portion of the conduction path situated between the peripheral sensory neurone systems and the neurone system extending from the diencephalon to the somæsthetic area of the cortex. Roundabout routes are made through the cerebellum by way of Gowers' tract and the direct cerebellar tract to the cerebellum, and by way of the brachium conjunctivum from the cerebellum to the red nucleus. From the red nucleus a neurone system extends higher up, probably to the cortex, possibly indirectly, by way of a new neurone whose cell body is situated in the hypothalamus. The conduction path just described is diagrammatically illustrated in Fig. 972.

The peripheral sensory neurones of the path concerned in bodily sensation have their cell bodies situated in ganglia. These cell bodies give off an axis-cylinder process which bifurcates T-shaped to form two fibres. One of these fibres runs to the periphery, the other into the central nervous system. That going to the periphery is the stronger, the central fibre being of smaller calibre. The bundle of medullated central fibres from a given ganglion forms the dorsal root of one spinal nerve. The peripheral fibres are connected in their distal parts frequently with special kinds of terminal sensory apparatus; sometimes they end free in among the cells of the tissues at the periphery. The central fibres entering the spinal cord un-

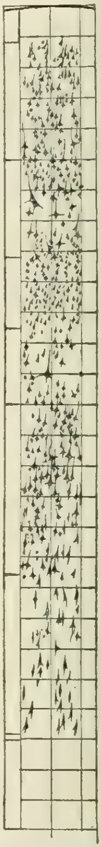

FIG. 969.—Section through the Cortex of the Gyrus Occipitalis Superior. (After C. Hammarberg, "Studior ofver Idiotiens Klinik och Patologi, etc., Upsala, 1893, Taf. ii., Fig. 4.)

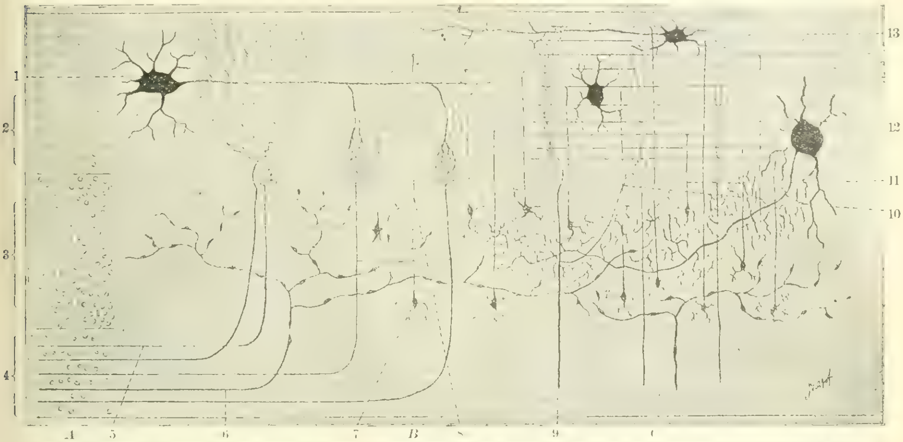

FIG. 970. Schematic Diagram of the Cerebellar Cortex. (After Bohm u. von Davidoff, "Lehrbuch der Histologie des Menschen," S. 279.) *A*, Ordinary nuclear staining (the layer of Purkinje cells is omitted); *B*, section vertical to the surface of a convolution; *C*, longitudinal section through a convolution. *B* and *C* by the chrome-silver method. 1, Stellate cell; 2, molecular layer; 3, granular layer; 4, medullary layer; 5, axone of a Purkinje cell; 6, moss fibre; 7, cell of granular layer; 8, axone of cell of granular layer; 9, climbing fibre; 10, telodendrion of collateral of climbing fibre; 11, axone of cell of granular layer; 12, large stellate cell; 13, stellate cell.

dergo Y shaped division with formation of a long ascending limb and a short descending limb. On their way they give off collaterals which run in to end in the gray substance, and the main fibres themselves ultimately terminate by running in to end in the gray matter of the central nervous system. The longest fibres from the dorsal roots reach the medulla oblongata and terminate in the nucleus funiculi gracilis of Goll or the nucleus funiculi cuneati of Burdach. The shorter fibres of the dorsal roots end in the gray matter of the central system near the point of entrance. The collaterals and terminals of the sensory fibres end in the spinal cord, chiefly about the cell bodies of neurones in the dorsal horns and in the middle zone of the gray matter. The axones of these cells carry impulses farther cerebralward. A certain number of collaterals, the so-called reflex collaterals, end about the cell bodies of the lower motor neurones in the ventral horns. Another group of collaterals crosses through the posterior commissure to end about the cell bodies of neurones in the gray matter of the opposite side of the cord. An important group of collaterals ends in among the cell bodies of the nucleus dorsalis (Clarke's column).

The sensory neurones of the second order of the conduction path now under discussion include the cell bodies of the nucleus funiculi gracilis and the nucleus funiculi cuneati and their axis-cylinder processes. The medullated axones from the perikaryons in these nuclei go as internal arcuate fibres to the middle line of the medulla oblongata where they cross over, decussating with similar fibres from the opposite side, to form the decussatio lemniscorum. On crossing, these medullated axones turn and run cerebralward, first in the stratum interolivare lemnisci, higher up forming the lemniscus medialis. These fibres in the lemniscus medialis are joined by medullated axones from the sensory nuclei of termination of the cerebral nerves. The fibres of the lemniscus medialis pass through the pons and enter the cerebral peduncle lying in its tegmental portion. They pass through the hypothalamus and end chiefly in the ventro-lateral region of the thalamus. Not all the fibres, however, of the lemniscus medialis reach this diencephalic termination. Many end in the pons and midbrain. From the ventro-lateral region of the thalamus, where the axones of the sensory neurones of the second order chiefly terminate, a new neurone system (sensory neurones of the third order) begins. The perikaryons of this neurone system are situated in the ventro-lateral nuclei of the thalamus. The medullated axones of these neurones pass through the internal capsule in the posterior part of its occipital subdivision and extend to the gyri of the cerebral cortex in the regions previously designated under the term somæsthetic area. According to the period of medul-

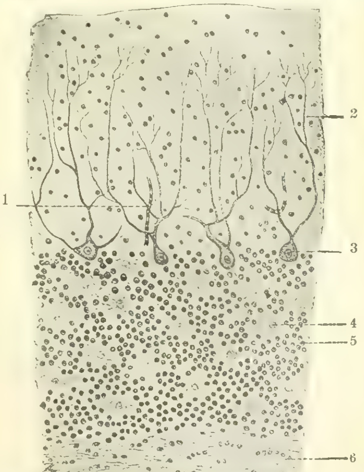

FIG. 971. A Section through the Cerebellar Cortex Stained with Hæmatoxylin and Eosin. (After Bohm u. von Davidoff, "Lehrbuch der Histologie des Menschen," S. 278, Fig. 197.) 1, Blood-vessel; 2, dendrite; 3, Purkinje cell; 4, large stellate cell; 5, cell of granular layer; 6, layer of nerve fibres.

lation, these diencephalo-telencephalic neurones are divisible into at least three systems (Flechsig).

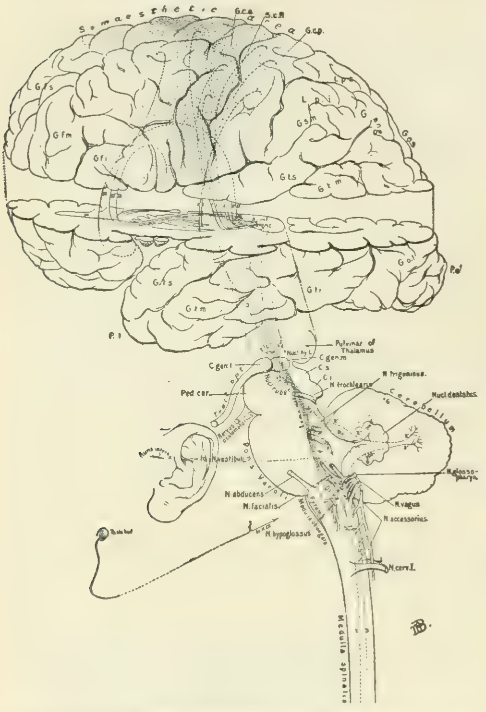

FIG. 972.—Scheme of General Somæsthetic Paths. (Taken by permission from "The Nervous System and Its Constituent Neurones," p. 744, Fig. 470, New York, D. Appleton & Co., 1900.)

While the above sensory neurones of the second order account for the further conduction of sensory impulses which reach the nuclei of Goll and Burdach in the medulla, there are other sensory neurones of the second order which carry farther cerebralward the impulses which are brought to the spinal cord by means of the shorter fibres of the dorsal roots and the collaterals of the longer fibres which end in the gray matter of the cord. These include the neurones, the axones of which make up the direct cerebellar tract, Gowers' tract, and the ground bundles of the lateral and ventral funiculi.

Those the axones of which make up the direct cerebellar tract have their cell bodies situated in the nucleus dorsalis (Clarke's column). The tract is first well marked in the lower part of the thoracic cord. The medullated axones run cerebralward in the dorso-lateral region of the lateral funiculus of the cord, pass through the corpus restiforme, and terminate chiefly, without crossing to the opposite side, in the vermis of the cerebellum.

Those the axones of which make up Gowers' tract have their perikaryons situated chiefly in the region of the gray matter of the cord, partly of the opposite side. The medullated axones run upward in the ventro-lateral region of the cord, pass through the medulla oblongata and pons as far as the level of the root of the trigeminal nerve. The fibres hook about this and then pass backward through the velum medullare anterius to end in the cerebellum.

The neurones of the second order whose axones run in the ground bundles of the ventral and lateral funiculi chiefly represent short tracts which run in to end in the gray matter of the central system at various levels, so that the conduction path of which these neurones constitute a member is probably a multiple-membered path.

The sensory neurones of the second order whose axones end in the cerebellum transfer their impulses in all probability to neurones of a higher order, the axones of which are represented by the fibres of the brachium conjunctivum. Many of these fibres end in the red nucleus of the opposite side. Others pass by the red nucleus and end in the hypothalamus. From the red nucleus and from the hypothalamic region neurone systems carry impulses through the posterior part of the internal capsule out to the somæsthetic area of the cortex.

The centripetal conduction path of taste is not so well known as some of the other conduction paths. The peripheral sensory neurones of this path include a portion of those of the nervus glosso-pharyngeus and probably also of the nervus trigeminus and nervus intermedius. The perikaryons of these neurones are situated in the ganglia on the roots of these nerves. The peripheral fibres run out to the tongue and are there connected with the peculiar bodies known as the taste buds. The central fibres of the n. glosso-pharyngeus and of the n. intermedius run into the medulla and are situated chiefly in the tractus solitarius. The central fibres of the n. trigeminus run into the pons in the sensory root of this nerve, there bifurcate into a short ascending limb and a long descending limb, the latter running down and helping to form the so-called tractus spinalis n. trigemini. These fibres give off collaterals which, together with the ultimate terminals, end in the gray matter which represents the nucleus of termination of the sensory part of the n. trigeminus. The central neurones of this path are very incompletely understood. Those of the second order have their perikaryons situated in the nuclei of termination of the n. glosso-pharyngeus, n. intermedius, and n. trigeminus. Their axones probably run longitudinally in the formatio reticularis. But the further continuation of the conduction path, the number of neurone systems superimposed in this path, and the cortical termination of the path are not yet satisfactorily understood.

The centripetal conduction path of smell has been in part carefully worked out. The peripheral sensory neurones of this path (olfactory neurones of the first order) include peculiar bipolar cells situated in the nasal mucous membrane. The central processes are non-medullated axones which perforate the cribriform plate of the ethmoid bone and terminate by multiple ramifications in the olfactory glomeruli of the bulbus olfactorius. The olfactory neurones of the second order have peculiar perikaryons, known as the mitral cells of the olfactory bulb. The impulses are brought to the perikaryons from the olfactory glomeruli by means of the dendrites of the mitral cells. The axones of these cells run through the olfactory tract, some of them entering the gyrus olfactorius lateralis, others the gyrus olfactorius medialis. A good many of the axones end in two small gyri in the uncus of the temporal lobe (gyrus semilunaris rhinencephali and gyrus ambiens). This is the temporal olfactory centre of Flechsig. Others of the fibres end in the gyrus subcallosus and the substantia perforata anterior (frontal olfactory centre of Flechsig). Some axones pass through the anterior commissure of the brain to the olfactory region of the opposite side. The connections of the temporal and frontal olfactory centres with other portions of the brain are very complex and special treatises must be consulted for a description of them. Some of them are shown in Fig. 973.

The centripetal conduction path concerned in carrying the visual impulses is made up as follows: The peripheral visual neurones or optic neurones of the first order are the bipolar cells of the retina. The optic neurones of the second order or central visual neurones include the cell bodies of the ganglion cell layer of the retina and their axones. The axones of these neurones run through the optic nerve to the optic chiasm, where part of them cross over, decussating with similar fibres of the opposite side. In the decussation the fibres from the lateral half of the retina run into the optic tract of the same side, while those from the medial half of each retina cross over to enter the optic tract of the opposite side. The fibres of each optic tract terminate chiefly in the lateral geniculate body, but some of the fibres terminate in the superior colliculus of the corpora quadrigemina and others in the pulvinar of the thalamus. These are the so-called primary optic centres in the brain. Extending from the primary optic centres, especially from the lateral geniculate body to the occipital cortex, is a third group of neurones (optic neurones of the third order), their cell bodies being situated in the primary optic centres and their axones running through the occipito-thalamic radiation of Gratiolet to terminate ultimately in the gray matter of the cortex of the occipital lobe, especially that about the fissura calcarina (Fig. 974).

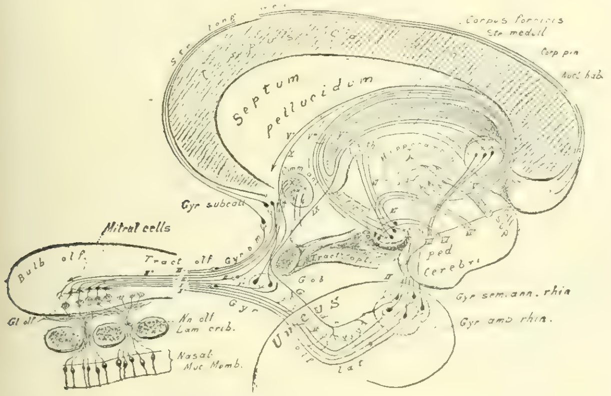

FIG. 973. Schematic Representation of Some of the Principal Neurone Systems of the Olfactory Conduction Path. Projected into sagittal plane. *Bulb. olf.*, bulbus olfactorius; *Col. forn.*, columna fornicis; *Col. sup.*, colliculus superior; *Comm. ant.*, commissura anterior cerebri; *Corp. mam.*, corpus mammillare; *Corp. pin.*, corpus pineale; *G. o. b.*, ganglion opticum basale; *Gl. olf.*, glomeruli olfactorii; *Gyr. amb. rhin.*, gyrus ambiens rhinencephali; *Gyr. olf. lat.*, gyrus olfactorius lateralis; *Gyr. o. m.*, gyrus olfactorius medialis; *Gyr. semiann. rhin.*, gyrus semilunaris rhinencephali; *Gyr. subcall.*, gyrus subcallosus; *Lam. crib.*, lamina cribrosa; *N. a. th.*, nucleus anterior thalami; *Nn. olf.*, nervi olfactorii; *Nucl. hab.*, nucleus habenulæ; *Ped. cerebri*, pedunculus cerebri; *Str. long. med.*, stria longitudinalis medialis; *Str. medull.*, stria medullaris; *Tract. olf.*, tractus olfactorius; *Tract. opt.*, tractus opticus; *I*, axones of mitral cells going to stria olfactoria lateralis; *I′*, axone of mitral cell terminating in gray matter of trigonum olfactorium; *II*, axone of mitral cell terminating in gray matter, whence axone goes to commissura anterior cerebri; *II′*, axones to anterior commissure; *II″*, centrifugal fibre terminating in bulbus olfactorius; *III*, axone of mitral cell terminating in gyrus olfactorius medialis; *IV*, axones of neurones connecting the olfactory portion of the uncus (gyrus ambiens and gyrus semilunaris) with the hippocampus (cornu ammonis); *V*, axones from hippocampus to fornix; *V′*, axone to commissura hippocampi; *V″*, axones from fornix to septum pellucidum; *V‴*, axones from fornix to corpus mammillare; *V⁗*, axone from fornix to nucleus habenulæ by way of the stria medullaris; *VI*, fasciculus mammillaris princeps; *VI′*, fasciculus thalamo-mammillaris Vicq d'Azyri; *VI″*, fasciculus pedunculo-mammillaris, pars tegmentalis (*Haubenbündel* of von Gudden); *VII*, fasciculus pedunculo-mammillaris, pars basilaris (pedunculus corporis mammillaris); *VIII*, fasciculus retroflexus Meynerti extending from the nucleus habenulæ to the ganglion interpedunculare. (Taken from "The Nervous System and Its Constituent Neurones," p. 779, Fig. 501, New York, D. Appleton & Co., 1900.)

The centripetal conduction path which carries the impulses concerned in hearing is a complex path. The peripheral auditory neurones (auditory neurones of the first order) have their cell bodies situated in the spiral ganglion of Corti. Their peripheral processes run out to end free in among the cells of the organ of Corti; their central processes run in through the cochlear nerve to terminate in the pons, chiefly in the nucleus n. cochleæ ventralis and the nucleus n. cochleæ dorsalis. In these two nuclei are situated the cell bodies of the majority of the auditory neurones of the second order. The axones from the cell bodies in the ventral cochlear nucleus go to form the main portion of the corpus trapezoideum, the fibres of the two sides decussating in the middle line. These axones terminate in part in the superior olivary complex of the opposite side, but some of them run forward in the lateral lemniscus of the opposite side. The axones from the dorsal cochlear nucleus run through the striæ medullares and plunge down to the region of the superior olivary complex of the opposite side, where some of them terminate, others entering the lateral lemniscus of that side. The lateral lemniscus receives also axones from cell bodies situated in the superior olivary complex. In the pons, then, the lateral lemniscus represents the main

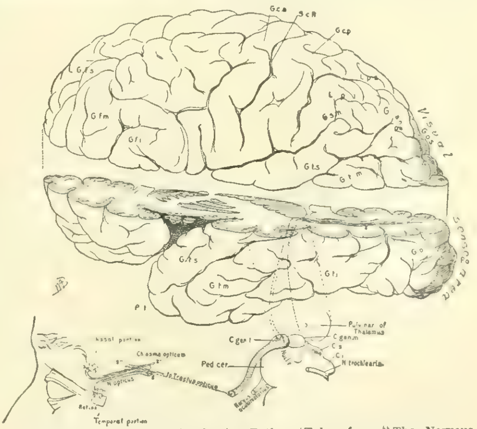

FIG. 974.—Scheme of Visual Conduction Path. (Taken from "The Nervous System and Its Constituent Neurones," New York, 1900, p. 833, Fig. 533.)

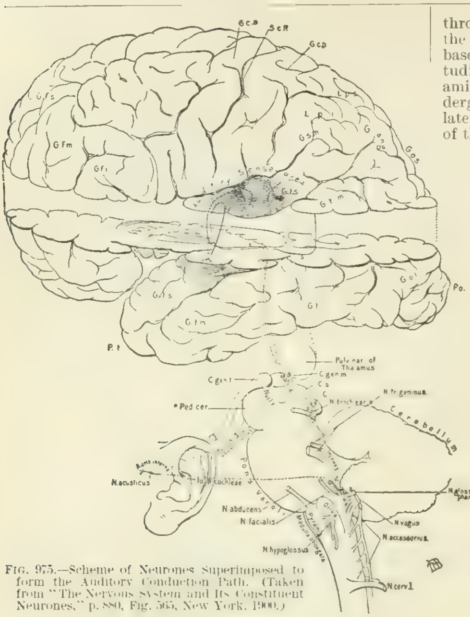

FIG. 975.—Scheme of Neurones Superimposed to form the Auditory Conduction Path. (Taken from "The Nervous System and Its Constituent Neurones," p. 880, Fig. 565, New York, 1900.)

conducting path for auditory impulses toward higher centres. A large proportion of these fibres terminate in the nucleus colliculi inferioris of the corpora quadrigemina, which therefore represents a very important way-station in the auditory conduction path. Some of the fibres of the lateral lemniscus run past the inferior colliculus and terminate first at a higher level. These fibres are joined by the axones of neurones whose cell bodies are situated in the nucleus colliculi inferioris. The conjoint bundle is known as the arm of the inferior colliculus (brachium quadrigeminum inferius). These fibres terminate chiefly in the corpus geniculatum mediale, though some go by it. In the corpus geniculatum mediale are situated the cell bodies of neurones, the axones of which run out through the posterior part of the occipital limb of the internal capsule to terminate in the cortex of the temporal lobe. This auditory centre in the temporal lobe is situated at the junction of the third and fourth fifths of the gyrus temporalis superior and includes the two transverse temporal gyri situated in the fossa Sylvii. The main features of this conduction path are illustrated in Fig. 975.

The principal centrifugal conduction paths to be considered are: (1) the general cortico-muscular conduction path; (2) the frontal cerebro-cortico-pontal path, and (3) the temporal cerebro-cortico-pontal path.

The cortico-muscular conduction path consists of at least two sets of superimposed neurones. The upper set of motor neurones consists of neurones whose cell bodies are situated in the motor region of the cerebral cortex (central gyri and paracentral lobule). They include the large pyramidal cells of this area. Their medullated axones are those of the so-called pyramidal tract. These axones descend through the corona radiata, through the anterior two-thirds of the posterior limb of the internal capsule through the middle portion of the base of the cerebral peduncle, form the bulk of the longitudinal fibres in the basilar part of the pons and the pyramids of the medulla. The majority of the fibres undergo decussation in the medulla and pass down in the lateral funiculus of the opposite side of the cord. Some of the fibres do not decussate but pass down chiefly in the ventral funiculus of the same side of the cord. A few of the uncrossed fibres descend in the lateral funiculus of the same side of the cord. The axones of the pyramidal tract terminate in the gray matter of the pons, medulla, and spinal cord.

The impulses running along the upper motor neurones are transferred to the lower motor neurones. The lower motor neurones have their cell bodies situated in the so-called motor nuclei of the cerebral nerves and in the ventral horns of the spinal cord. Their axones form the motor roots of the cerebral nerves and the ventral roots of the spinal nerves. They run out to the various muscles of the head, trunk, and limbs (Fig. 976).

The frontal cerebro-cortico-pontal path consists of a set of neurones whose cell bodies are situated chiefly in the feet of the frontal gyri. Their medullated axones descend through the corona radiata and through the anterior limb of the internal capsule to the base of the cerebral peduncle occupying its most medial region. These fibres terminate in the pons among the cell bodies of the nuclei pontis.

The temporo- and occipito-cerebro-cortico-pontal path consists of neurones the cell bodies of which are situated in the temporal and occipital lobes of the brain. Their axones descend to

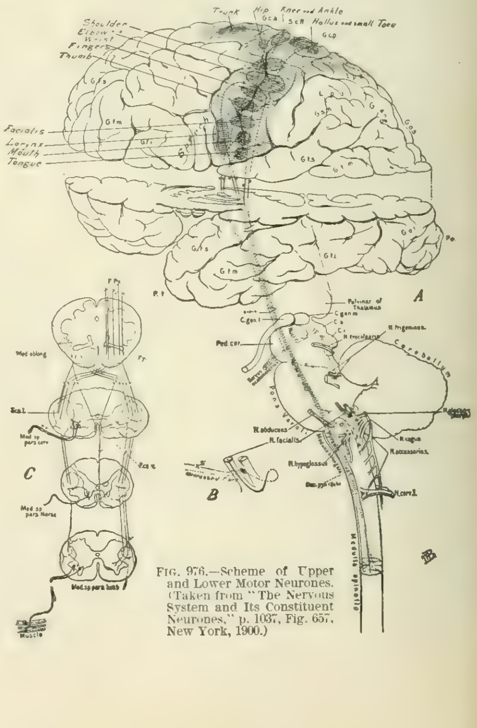

FIG. 976.—Scheme of Upper and Lower Motor Neurones. (Taken from "The Nervous System and Its Constituent Neurones," p. 1037, Fig. 657, New York, 1900.)

the base of the cerebral peduncle, where they form the lateral mass of fibres. Passing through the peduncle they terminate in the nuclei pontis. From the nuclei pontis go off axones through the brachium pontis of the cerebellum, there to communicate with cerebellar neurone systems which in turn are capable of throwing the lower motor neurones under their influence.

A word must be said concerning the commissural neurones and the associative neurones of the telencephalon. Of the commissural neurones the most important are: (1) those whose medullated axones make up the corpus callosum; (2) those whose medullated axones constitute the principal part of the anterior cerebral commissure, and (3) those whose medullated axones make up the commissura hippocampi.

The medullated axones of the corpus callosum connect the two hemispheres with each other, possibly identical portions of the two hemispheres. The anterior commissure of the brain may be looked upon as a supplement of the corpus callosum. It is generally supposed that this commissure connects the temporal lobes, the basal surface of the occipital lobes, and the olfactory bulbs with one another, the corpus callosum connecting similar portions of the rest of both cerebral hemispheres. The fibres of the commissura hippocampi, or so-called "lyre of David," connect the hippocampus of one side with that of the other. It is probably to be regarded as an olfactory commissural path.

The association neurones of the telencephalon connect a portion of one hemisphere with another portion of the same. Some of them have short axones, others have long axones. Those with short axones connect adjacent gyri, those with long axones connect distant gyri, with one another.

The association neurones with short axones include the fibræ propriæ of the cerebral gyri. In the occipital lobe a number of neurone systems with short axones have been worked out. They include the stratum calcarinum, the fasciculus occipitalis verticalis, the fasciculus occipitalis transversus cunei, fasciculus occipitalis transversus gyri lingualis, and the stratum proprium.

The association neurones which have long axones include the cingulum, the fasciculus longitudinalis superior, the fasciculus uncinatus, the association bundles of the fornix, and the tapetum.

The cingulum is an olfactory tract which extends in a sagittal direction in the white matter of the two main parts of the gyrus fornicatus, namely, the gyrus cinguli and the gyrus hippocampi.

The fasciculus longitudinalis superior is a curved bundle extending in a sagittal direction, apparently between the frontal lobe and the occipital lobe (Fig. 977).

The fasciculus longitudinalis inferior is usually described as extending between the lobus occipitalis and the lobus temporalis. The anterior part of the fasciculus, however, is difficult to differentiate, and accordingly its anterior connections are disputed.

The fasciculus uncinatus extends between the uncus and the basal portions of the frontal lobe. It is probably olfactory in function. The fornix contains the medullated axones of many association neurones. One important bundle connects the hippocampus with the substantia perforata anterior and is probably olfactory in function.

The tapetum is an association bundle connecting the occipital lobe with the frontal lobe (Dejerine).

Lewellys F. Barker.

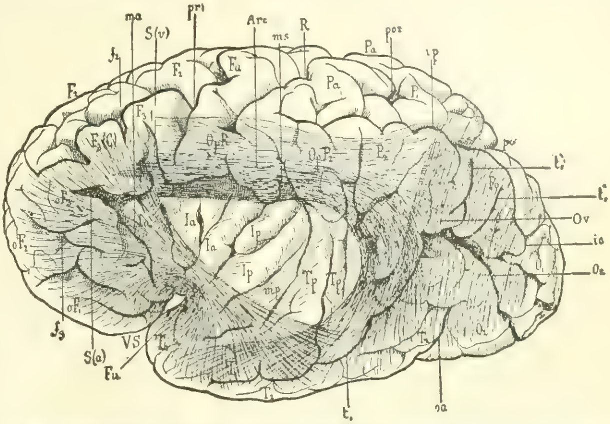

FIG. 977.—Lateral Surface of the Left Cerebral Hemisphere. The edges of the fissura cerebri lateralis (Sylvii) have been pulled apart to show the insular and retroinsular region. The fasciculus uncinatus, the fasciculus longitudinalis superior, and the fasciculus occipitalis verticalis are seen in transparency. (After J. Dejerine, "Anatomie des centres nerveux," Paris, 1895, p. 757, Fig. 377.) *Arc*, Fasciculus longitudinalis superior; F_1, F_2, gyrus frontalis medius and gyrus frontalis inferior; f_1, sulcus frontalis inferior; f_2, sulci orbitales; F_3 (C), gyrus frontalis inferior pars triangularis; *Fa*, gyrus centralis anterior; *Fu*, fasciculus uncinatus; *Ia*, *Ip*, gyri insulæ; *ip*, sulcus interparietalis; *ma*, *mp*, *mf*, sulcus circularis Reili; o_1, o_2, gyri occipitales; *oa*, sulcus occipitalis anterior of Wernicke; oF_1, oF_2, oF_3, orbital portion of frontal gyri; *OpR*, operculum, pars frontalis; OpP_2, operculum, pars parietalis; *Ov*, fasciculus occipitalis verticalis; P_1, lobulus parietalis superior; P_2, lobulus parietalis inferior; *Pa*, gyrus centralis posterior; *Pc*, gyrus angularis; *Po*, fissura parieto-occipitalis; *por*, portion of sulcus interparietalis behind the upper part of the gyrus centralis posterior; *prc*, sulcus praecentralis; *R*, sulcus centralis Rolandi; *S* (*a*), *S* (*v*), anterior and vertical ramus, anterior horizontalis, and ramus anterior ascendens of fissura cerebri lateralis Sylvii; T_1, gyrus temporalis superior; T_2, gyrus temporalis medius; t_1, sulcus temporalis superior; t', t', vertical rami of the sulcus temporalis superior; *Tp*, gyri temporales transversi; *VS*, fossa cerebri lateralis Sylvii.

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BRAIN: HYDROCEPHALUS.—See *Hydrocephalus.*

BRAIN, HYPERÆMIA OF.—A term used to signify augmentation of the mass of blood in the vascular department of the brain. An equivalent meaning is conveyed by cerebral congestion. Both terms indicate in the main an extra-physiological accumulation in the circulation of the encephalon, and express the same cause united to different symptoms, although congestion seems to apply rather to the sudden or the so-called fluxionary hyperæmia resulting from pathological conditions in other parts of the body. Some writers claim that increase of arterial blood passing through the encephalon is the only true hyperæmia, and that fulness of the brain should more properly be described by "venous congestion," which is associated with the anæmia consequent upon impaired vaso-motor innervation of the neurasthenic state.

Like that of many questions in medicine, the history of cerebral congestion is old, and so completely chaotic that in recent times the possibility of its occurrence, and consequently its clinical importance, have been doubted. Putting aside its existence as a separate disease, or as a morbid entity having pathognomonic and regular symptoms, we will assume that the brain, like any other organ, may be the seat not only of anæmias but of hyperæmias either circumscribed or generalized. Analogical justification so obvious as that furnished by experimental investigation on the lower animals, having reference to venous hyperæmia, renders the possibility of increased vascularization of the brain admissible. Further evidence that the contents of the cranial cavity may vary in quantity is furnished by the intracranial pressure detected in infants in whom the fontanels are open, the scalp being raised above the level of the skull, or depressed, according as the head is raised or lowered, or when the tension of the fontanel is increased by compression of the jugular veins. When a portion of the brain is exposed, after an injury of the skull, it will be observed to enlarge and to contract in correspondence with the elevation or depression of the head, the presence or absence of sleep and emotional excitement, or with the action of any cause that accelerates the circulation. Any cause that constricts the neck may produce a sensation of fulness and pain about the head, with bleeding from the nose; and as a fact of pathological moment that should be emphasized, there may be mentioned the obstruction to the flow of venous blood resulting from insufficient removal of carbon dioxide. In dependent positions of the head, indications of congestion are noticeable in the bloodshot countenance and other evidences of imperfect return of blood. The existence of intracranial congestion in such circumstances is further demonstrated by the very red papillæ and much-congested vessels of the optic nerve. These changes at the fundus of the eye are not found in such gymnasts as trapeze performers and "fly walkers," because by constant training and habit the animal economy accommodates itself to the abnormal positions. Variability of the cerebral circulation is further shown in the pallor of the fundus of the eye, following the administration of drugs that are known to irritate the vascular nerve centres, as ergotin and belladonna. Finally, the existence of cerebral hyperæmia is revealed by the necroscopic appearance of the brains of persons or of animals who during life suffered from interruption to the perfect return of blood from the head.

Pathological Anatomy.—It is quite difficult to recognize cerebral hyperæmia on the cadaver, since evident traces are not always left in the brain, and there may be sanguinary stases brought about by gravity and the position of the cadaver which do not exist during life. Venous hyperæmia is more easily recognizable after death than the arterial form. In a severe case of hyperæmia the tissues over the cranium are often found to contain an abnormal quantity of blood; drops of extravasated blood from ruptured vessels are seen on the dura after removing the calvarium; the dura, when detached, is of a bluish tint; the sinuses of the dura, the veins emptying into the sinuses, the veins of the pia and the choroid plexuses are distended with blood; and degeneration of the vessels themselves has been frequently observed. The mass of the brain appears larger and swollen, the gyri are flattened, the sulci effaced, and the ventricles may be filled from subarachnoidean effusion; there is a reddening of the whole organ, and the membranes are dry and viscous. This reddish or deep-red tint is particularly noticeable in the intense hyperæmia of the new-born.

The gray substance, increased in consistence, presents a reddish-gray color, and if the hyperæmia has been intense, small punctiform hemorrhages are observed. The white substance, also increased in consistence and in density, is of a uniform rose color. On section the brain, without being œdematous, shows numerous sanguinary points which are larger than usual, owing to increased size of the capillaries. The meninges are usually filled, and the veins of the cortex are tortuous. If the case has been a chronic one, uniform widening and tortuosity of the vessels are much more pronounced, showing the development of small aneurismal dilatations, and sequelæ conditioned by the increased vascularization, such as vascular development of the cellular tissue which enters into intimate relations with the glia. The cribriform or sieve-like appearance observed on making a transverse section of the hemispheres is usually regarded as a consequence of long-standing stasis, especially if found in the brains of old people, of chronic drunkards, of opium-eaters, or of maniacs. There are also reasons for believing that cerebral atrophy may be developed in old people in consequence of continuous venous stasis. The pathological changes of arterial hyperæmias peculiar to the cranial cavity are rarely observed on the cadaver, as they usually disappear, with its causes, after death. When we take into consideration the imperfect knowledge both of its mechanism and of its anatomical details, and the difficulty to establish the relations existing between its numerous symptoms and the lesions that determine them, it is not surprising that the existence of cerebral hyperæmia is not always easily demonstrable. The condition may sometimes be studied on the large arteries of the pia, but no one has yet distinguished an arterial from a venous hyperæmia in the cortical portion of the brain. It is only in such processes as Basedow's disease that chronic arterial hyperæmia is recognized. The difficulty of recognition is increased by the inflammatory changes and simple hyperplasias that are often present, and often overlooked after frequent and long-continued attacks of chronic arterial hyperæmia. According to recent researches, when the disorder has run a rapid course pathological changes may be found in the ganglion cells, or in the cortical connective tissue, with nuclear proliferations in the walls of the vessels, and in the fibrillary plexus of the cortical substance.

Etiology.—If there exists a disproportion between the clinical and the post-mortem phenomena of cerebral hyperæmia, it must be admitted that the mass of the blood within the skull varies according to certain circumstances, and that the brain, like other organs of the body, is subject both to anæmia and to hyperæmia; indeed, it would be surprising if it were not. The question of hyperæmia resolves itself into that of a liquid circulating in tubes, in which repletion or engorgement can be produced in but two ways, namely, by increase of the inflow, or by diminution of the outflow. Active fluxionary hyperæmia may be caused by the augmentation, and passive hyperæmia, or that of stasis, by diminution of the sanguinary flow. The force and abundance of the inflow of blood into the vessels of the brain are influenced by the general increase of pressure, and by diminution of local resistance, and it seems as if the greater number of active congestions should be brought under the first category. For a long time the congestive influence of certain exciting drinks, as tea, coffee, and alcohol, has been admitted; and violent muscular exertion, general plethora, cardiac hypertrophy, emphysema of the lungs, the effects of strong emotion, and the exaggeration of normal functional activity, are believed to take great part in the production of cerebral congestion. But the general increase of blood pressure plays simply a secondary part in the production of hyperæmia, which it can facilitate or augment only when there exist local alterations, such as inflammations or vascular lesions. Hypertrophy of the heart can scarcely be said to cause congestion of the brain, except in cases in which the cerebral vessels have become weakened on account of other causes, and the same may be said of other agents that increase the cardiac impulse.

Other conditions that tend to produce congestion of the brain, by excess of arterial tension and too considerable afflux of blood, are chronic Bright's disease, Basedow's disease, intermittent fever, extremes of heat and cold, and the tension produced in the vessels of the head and neck when the aorta is constricted or strongly compressed by a thoracic or an abdominal tumor. This increased arterial tension may also be brought about by the suppression of the normal or pathological secretions, as the menses at the menopause or other period, by the sudden stoppage of hemorrhoidal bleeding when general plethora exists, by the checking of a chronic diarrhœa of long standing, or by stopping the hemorrhages in hæmatophilia, and it may result from facial erysipelas, or any cerebral or meningeal phlegmasiæ, from diverse peripheral irritations, from extended lesions of the skin produced by burns and eruptive diseases, as variola, scarlatina, and measles.

An important and considerable class of congestions may result from local increase of pressure or collateral fluxions, by means of which the entrance of blood is shut out from the organs. The pathological phenomena susceptible of giving place to collateral fluxions are acute inflammations, thromboses, and embolisms, and the infarctions resulting therefrom. Interstitial hemorrhage may have the same result; and the energetic local compression excited on the skin by the application of thick layers of collodion also produces a considerable local hyperæmia. Fluxionary hyperæmias from exaggeration of pressure result from general pressure only, not from local, and the greater part of them result from the pathological causes above mentioned.

Hyperæmias of fluxion, by diminution of local resistance, may result when atmospheric pressure is diminished or defective, the simplest type of which is furnished by the application of the large exhausting apparatus used to produce cutaneous revulsion. The opposite condition may bring about the hyperæmias peculiar to workmen in condensed air (see *Caisson Disease*). The congestive phenomena brought about by the rapid disappearance of a considerable effusion, as ascites, and even by the extirpation of certain tumors, belong to the same category. The condition is also brought about by direct or reflex paralysis of the vaso-motors which influence the dimensions of the vessels in the brain cavity. The innervation of the vascular walls may be directly diminished by any pressure whatever, as that of a tumor, or they may be paralyzed by reflex action in consequence of an irritation of the sensitive nerves of a part, as observed in inflammation and in lesions of the nerve centres. Direct paralysis of the muscular walls of vessels may be brought about by variations of temperature. Extreme heat and cold and insolation are capable of producing intense congestion, and the action of rubefacients is analogous. Direct insolation doubtless acts by raising the temperature of the cranium to such a degree as to cause incipient paralysis of the muscular action of the vessels, and consequent diminution in the tonic force of their walls. The same nervo-vascular phenomena are asserted to be brought about by the action of such substances as opium, alcohol, belladonna, hyoscyamus, hasheesh, stramonium, and amyl nitrite. Fatty or amyloid degeneration of the vascular walls, especially in old people, transforms the vessels into inert and dilatable tubes, which may favor hyperæmias of this order. The presence of entozoa, or of any pre-existing focus of disease in the brain, is also an etiological factor. Finally, all the processes that decrease intracranial pressure favor the creation of cerebral hyperæmia. Among them must be reckoned such causes as intense excitement, no matter whether produced by imagination, temperament, or thought. Intellectual work that consists in logical combinations of ideas seems to be less hurtful in this respect than the more exciting results of a heated imagination, or the depressing effects of sadness, sorrow, and sudden shocks.

Passive hyperæmia, or the hyperæmia of stasis, may result from the active or fluxionary form. It happens that the capillary vessels do not regain their first tonicity after the enormous distention of an active hyperæmia, so that the stases become confused with the preceding fluxions. The causes of hyperæmia by stasis are principally those that retard the return of blood from the brain, either by diminution of the local pressure or by increase of the obstacles opposed to the returning circulation. The former exists in the case of alterations of the arterial walls, or when their contractility and elasticity are lost, and in obliteration of the arteries; the second is seen in the hypostases of certain congestions resulting from the long continuance of one position of the body, or in those following certain maladies, and in the compressions of the venous system by tumors or any neoplasm whatever. Venous congestion or hemorrhagic stasis may result from thrombosis, or it may result from congestion of the vena portæ, from compression of the jugular, from a stasis in the region of the lesser circulation, from mitral insufficiency, emphysema, and stenosis of the larynx, from all forced expiratory efforts made with closed glottis, and from all processes that invade the abdominal cavity, especially in plethoric individuals. Chronic constipation and flatulence, blowing wind instruments, violent vocal efforts, parturition, epilepsy, hysteria, and chlorosis — these causes are all at fault in producing this variety of hyperæmia.

SYMPTOMS.—Although no one sign of cerebral hyperæmia is of absolute diagnostic value, yet its existence is often established by the symptoms alone. Fluxionary hyperæmia constitutes rather a phenomenon superadded to various morbid states, but in certain cases of mental alienation over-activity of the mind, though always secondary, is very nearly the only pathological manifestation. As in anæmia, the symptoms met with in exaggerated distention of the vessels of the brain are those arising from derangements of the sensorium, the organs of special sense, and of the sensitive and motor nerves. The manifestations of cerebral hyperæmia are perhaps better known to alienists and neurologists than to other physicians. They are most important as throwing light on the general pathology of insanity, many cases of which, having unknown or undetermined lesions, are doubtless owing to encephalic congestions. Of the cerebral functions the most strongly affected is the intelligence. Delirium is the prominent symptom of cerebral hyperæmia. It is generally that of excitement, and in many cases in no way connected with general paralysis there are found to predominate the delusions of grandeur, riches, ambition, and the like, characteristic of congestive mania. The superactivity of the cerebral circulation, as well as that of thought and well-being, may be recalled in the rosy excitement produced by wine and good cheer, in the artificial excitement of poetic frenzy, in the beatific visions of psychopathic women, and in religious ecstasy. Insomnia is one of the surest signs of hyperæmia of the brain. In many cases mania and certain hallucinations are connected with a notable hyperæmia of the gray layer. The delirium of febrile congestion, which is of a more distressing character, is owing less to quantity than to the quality of the blood, which is warmer, and besides charged with pyrogenic substances, as miasms, pus, and the like.

DIAGNOSIS.—General hyperæsthesia most often coincides with furious delirium, and headache also exists in a great number of cases. The troubles of the organs of sense are characterized by excitement and irritability.

It is claimed that paræsthesia may be detected with the æsthesiometer. Generally the pupil is contracted. This has been noted in the greater proportion of cases. Paralysis of the dilator or irritation of the sphincter is met with. Photophobia, ocular spectra, and ringing in the ears are symptoms peculiar rather to cerebral anæmia or to the venous variety of hyperæmia. The ophthalmoscope teaches but little in regard to cerebral hyperæmia. Its use has, however, justified the supposition of a transitory vaso-motor paralysis during frequent and severe attacks of cerebral congestion in a case of hysteria with paralysis and other symptoms. Diplopia and illusive transformations of hearing are often present with the other derangements of the special senses. Recent observations point to the connection between tympanic congestion and cerebral hyperæmia. Examination of the membrana tympani appears to indicate the state of the cerebral circulation, a fact demonstrated by comparing the state of this membrane before and after the administration of quinia or amyl nitrite. It is remarked, in connection with this circumstance, that evidences of congestion are noticed in the vessels over the handle of the malleus, and that the membrana tympani is of a light pinkish color. There is also a rise of temperature in the external auditory canal.

Motor disorders are seen in the agitations and struggles of the patient. There may be numbness and formication of the extremities, but paralysis does not in any way belong to arterial hyperæmia. Convulsions are most common in infants, and belong rather to anæmia or venous stasis than to arterial hyperæmia, and they may be confounded with epilepsy. The vomiting sometimes met with belongs also most often to anæmia. The circulatory apparatus is more or less disturbed in cases of active congestion. There are palpitation and a sense of oppression; the pulse is full and rapid and the carotids pulsate. This morbid excitability of the heart is particularly influenced by emotional disturbance. There is, however, a difference of opinion as to its symptomatic importance. Reflex excitability is preserved.

The phenomena of *venous or passive congestions* are in reality those that commonly relate to anæmia of the brain, and in a given case of anoxyhæmia it is difficult to recognize whether the condition be owing to want of blood in totality or to venous stasis. In a venous stasis from thrombosis of the sinuses or from embolism the symptoms present are similar to those of congestion, namely, derangements of the intelligence, the sensibility, and the motility, and sometimes there is an agitated state of mind, with dilated pupils. Vertigo, photophobia, auditory subjective phenomena, and incoherence of ideas exist, however, to a less degree in this form than in the fluxionary, and in the case of delirium it is rather of the mild or demented kind. The symptoms may vary according to age, sex, and other circumstances. Men are more subject than women. The different periods of life known as increase, maturity, and decline are modifying influences, but it does not appear that season exerts any influence. The symptoms may be light or severe, and they may be acute or chronic.

In a case of acute *fluxionary hyperæmia* the patient may, after a short premonitory headache and dizziness, fall senseless, with or without convulsive movements. The face is red, the conjunctivæ are injected, the pupils contracted, the temporals and carotids pulsate vehemently, the pulse is hard and strong, the respiration stertorous. There are often convulsive movements and twitchings, especially in children, combined with slight paresis, and the condition often ends in stupor and death. If the case does not terminate fatally, the symptoms decrease in severity and disappear entirely, or they may pass into the chronic form. The latter is characterized by a sense of fulness and heaviness in the head, by continuous or paroxysmal headache, dizziness, and pulsations of the temporal and carotid arteries. These symptoms become worse by lowering the head, and by the influence of alcohol, if the hyperæmia is still active. The frame of mind is rarely serene, the patient is morose, excitable, and explosive. There is a disinclination to mental labor, with confusion of thought, the combinations of which are illogical, morbid, and exaggerated; and symptoms of morbid apprehension, like those common to agoraphobia, are often present. A morbid fear of impotence is a predominant idea in this condition. Other symptoms arrange themselves according to the fundamental conditions that originate the exaggerated distention of the cerebral vessels.

The symptoms of *passive hyperæmia* are not entirely identical with the foregoing. There is more apathy, and the patient is more depressed. It should be taken into account that the poisonous influences of carbon dioxide obtain in this condition: it is the defect of oxygen in the venous blood, and not its quantity, which causes the characteristic phenomena.

Diagnosis.—The diagnosis of cerebral hyperæmia is often not clear, because of the likeness of the symptoms to those of anæmia. The question here concerns the symptoms that have already been mentioned in connection with the excitements of the three great faculties of the nervous system, another enumeration of which would be tedious. In the delirium of anæmic origin, as in grave fevers and inanition, the aspect of the patient is quite the opposite of the flushed face, the brilliant eye, and general rugged appearance so often associated with hyperæmic delirium. The essentially transitory character of the excitement met with in these cases, the syncope and convulsions, leave no doubt as to the anæmic cause of the delirium. Delirium tremens and a certain kind of delirium from lead-poisoning resemble in some points the delirium of cerebral hyperæmia, but the discrimination is easy when attention is directed to the history of the case and a knowledge of the patient's habits. Elevation of temperature is of use in distinguishing inflammatory diseases of the brain from hyperæmia. The latter condition is usually apyretic, but at times it is possible to detect an elevation of one or two degrees above the normal by means of the differential calorimeter applied to different regions of the head. Vertigo, epilepsy, uræmia, embolism, thrombosis, softening, and hemorrhage may be confounded with cerebral hyperæmia; but each of these affections may be distinguished after careful examination into the condition of the urine, heart, lungs, and blood-vessels, and on comparing the symptoms of the afore-mentioned diseases with those of hyperæmia.

Prognosis.—The prognosis of cerebral hyperæmia depends upon the intensity and duration of the symptoms as well as on individual circumstances. Children are more liable to succumb to the intensity of congestion, and in old people cerebral congestion is particularly dangerous because of the tendency to rupture in the degenerated vessels. Strong cerebral congestions are as grave as cerebral hemorrhage, and may lead to death. They may also prove the immediate cause of death in such chronic conditions as tumor of the brain and senile degeneration of its vessels. The tendency to such secondary lesions as hemorrhage, softening, cerebritis, and the like is greatly increased by the frequency of the paroxysms. Active cerebral hyperæmia, being more amenable to treatment, is consequently more favorable to recovery than is the passive variety.

Treatment.—The chief therapeutic indication in acute fluxionary hyperæmia is to diminish the sanguineous afflux, and this is perhaps best done by judicious inaction and careful watching of the symptoms. The condition is not one either of pressure or of œdema, but of an over-active circulation, and the treatment must vary according as the causes are primary or secondary. The nature of the treatment of active congestion from such causes as extremes of temperature, insomnia, or other irritable condition of the brain will, of course, differ from that required by the secondary congestions caused by suppression of the menses, by gout, or by rheumatism. Rest and position are of primary importance during an attack. The head should be elevated and the arms stretched upward. Quiet surroundings, fresh air, and a darkened room are advisable. Local bleeding is recommended by most practitioners, but it should be done with a certain amount of discretion and caution. As a rule it is contraindicated in children and old people, and in hysteric or chlorotic persons. The so-called derivation and revulsion, in which a considerable congestion of the whole or part of the intestinal canal is produced by the administration of a drastic purgative, may diminish the afflux of blood to the brain. In fact, main reliance is to be placed upon the derivative effects of croton oil, colocynth, and irritating enemata, as of vinegar; the irritation of hot or mustard baths for both the hands and feet; and the production of diuresis. Reflex action is further brought about by the application of a mustard plaster to the epigastrium, and of the actual cautery to the nape of the neck. Cold vigorously applied to the head, in the form of ice, or cold douches upon the head, combined with a hot bath, are adjuncts in the treatment too valuable to be overlooked. When there is a heart complication it may be met with cardiac medicaments. Among the internal remedies that it is advisable to employ as agents in relieving the cerebral congestion are the bromides, ergot, oxide of zinc, eucalyptus, and hydrobromic acid. When the symptoms of congestion have disappeared, strychnia, phosphorus, and cod-liver oil may be administered with advantage, and at the same time the patient's nervous system is to be carefully nursed. This is particularly to be enjoined in the case of chronic hyperæmia. Complete intellectual rest, fresh air, regular habits, and the disuse of tea, coffee, alcohol, and tobacco should form part of the hygienic treatment. The milk cure and the grape cure may be mentioned as valuable dietetic measures. If the congestion arises from stoppage of a hemorrhoidal flow, leeches may be applied to the anus. Wonderful effects have been thus brought about. Like results have been obtained by applying leeches to the mouth of the uterus in secondary hyperæmia caused by suppression of the menses. In this condition the electric brush applied to the thighs, with douches to the loins and perineum, has been found efficacious in restoring the menses. Galvanization of the head and of the sympathetic nerve, having the power to contract the cerebral blood-vessels, may often be used with good effect. A systematic course of hydrotherapeutics is often advantageous.

In passive hyperæmia the causes are to be made the special objects of treatment. Generally, it is a question of restoring vascular tonicity and combating symptoms that in many respects resemble those of cerebral anæmia. Stimulants may be administered in many cases. Satisfactory results have been obtained from ether inhaled in small quantities. The use of cardiac tonics, as digitalis, when the stasis results from some vascular or cardiac lesion, or when there is cirrhosis of the kidney, is a question that still admits of a satisfactory solution.

Irving C. Rosse.

BRAIN: LESIONS OF THE CORPORA QUADRIGEMINA.—In discussing the lesions of the corpora quadrigemina in man our material is scanty, and it is often impossible to distinguish between the results due to injury of one portion of the brain and those due to the destruction or irritation of neighboring parts.

The corpora quadrigemina of mammals correspond in structure to the optic lobes of frogs, birds, and fishes. Little is known about purely destructive lesions of the corpora quadrigemina in man. Experiments on animals would lead us to suppose that destruction of the whole corpora quadrigemina would result in complete blindness, and unilateral lesion in hemianopsia. In man, however, this does not always occur. In a case related by Eisenlohr, a revolver bullet entering through the forehead passed directly into the right corpus quadrigeminum and there remained. The power of sight was only partially lessened at first—R. $\frac{20}{20}$, L. $\frac{20}{70}$; later, R. $\frac{20}{70}$, L. $\frac{20}{200}$ (Monakow). Monakow concludes that the destruction of a whole anterior corpus quadrigeminum in man causes only moderate affection of sight and leaves the color sense intact. Local lesions of the corpora quadrigemina may cause dilatation of the pupils in one or both eyes and the pupillary reaction to light and accommodation may be much impaired. As the process advances toward the base, disturbances of the ocular muscles become prominent. Total ophthalmoplegia is rare, but there is paresis of the various muscles, not homologous, incomplete, and developing unevenly. The posterior corpora quadrigemina have nothing to do with sight; after isolated lesion of them no effect on vision is observed. Paralysis of the fourth nerve (unilateral or bilateral) and disturbances of chewing have been found in such cases. Lesions of the corpora quadrigemina also produce both ataxia of movement and cerebellar ataxia. Tremor resembling that of paralysis agitans and sometimes choroid movements either of the opposite extremities or bilateral may exist.

An important symptom in cases of lesion of the *posterior* corpora quadrigemina is a *dimunition of hearing* in the opposite ear.

In cases of tumor or foreign growth in the corpora quadrigemina or their neighborhood the adjacent regions are liable to be affected and symptoms strictly referable to the disturbance of these regions are apt to occur. These symptoms, as well as the general, that is non-localizing, symptoms of cerebral tumor cannot be discussed here, but must be considered as of much importance in forming the diagnosis. *William N. Bullard.*

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BRAIN: LESIONS OF THE CORPORA STRIATA.—By corpora striata is designated the lateral portion of the collection of gray matter called basal ganglia; these are further subdivided into two parts, the nucleus caudatus and nucleus lenticularis.

These parts of the brain are rarely if ever the seat of independent states of disease. The lesions found in this region of the brain are almost exclusively vascular or tumors.

The symptomatology of disease of the corpora striata is very obscure, and reports of pathological without distinct clinical findings are often met with.

The main symptoms to be expected from lesions in this neighborhood will be dependent upon implication of the adjacent capsular structures. As symptoms pointing with some probability to involvement of the corpora striata, these motorial irritation phenomena are cited: choreatic and athetotic twitchings and spasms or convulsive laughter or crying. *Joseph Fraenkel.*

BRAIN: MALFORMATIONS. See *Teratology.*

BRAIN: METHODS OF REMOVING, PRESERVING, DISSECTING, AND DRAWING.—§ 1. This article has no direct reference to microscopical or pathological requirements, which are provided for elsewhere in this work and in special papers.* Neither is it designed for neurological specialists, or for those who may have the benefit of their counsel, or access to large libraries; but physicians and students at a distance from medical centres, who desire to attain a real and personal acquaintance with the gross anatomy of the human brain as an aid to the comprehension of its minute structure, its functions, diseases, and mental relations, may profit from an account of the methods found useful in a laboratory where many students have prepared for a medical course.

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* For example, that of Donaldson, 1894; see the Bibliography at the close of this article.

§ 2. *Need of More Attention to the Subject.*—In the large city schools considerable time is now devoted to the anatomy and physiology of the nervous system, and instruction is given especially in histological methods; but even there the gross anatomy is not always adequately worked out by the student himself upon good material, and it is to be feared that in some institutions the conditions described seventeen years ago (W., 1884, *a*) may still prevail.

§ 3. Inasmuch as he is permitted to clean scrupulously the abdominal muscles before examining the vastly more important viscera, the average first-year student is at least consistent in deferring the removal of the organ of the mind until he has carefully dissected the muscle that wrinkles the forehead. With saw and chisel he lacerates the brain, tears it in the effort to save entire the sacred skull-cap; injures it yet more in the process of extraction,[*] and places it upon a hard, flat surface, where its own weight completes the rupture of delicate connections and hopelessly distorts its shape. Here he leaves it (having to clean some bones), perhaps for a day or two, probably drying, and either freezing or decomposing according to the temperature. He then transfers it to a basin or pail, covers it with strong alcohol, notes with satisfaction that the surface hardens rapidly, feels sure of finding out all about the brain, and sees himself a future neurological expert, perhaps even an asylum superintendent. In due time, armed with his "Gray" and a big knife, he succeeds in identifying the cerebellum, the chiasma, and the pons. Upon the cerebrum he recognizes the Sylvian fissure, but is doubtful about the central; moreover, the effort to detach the dried-on pia creates so many undescribed depressions and fissural confluences that he imagines, *à la* Benedikt, that it belonged to some hardened criminal. Lifting the occipital lobes, his fingers readily enter cavities which must be the "descending horns of the lateral ventricles," a triumphant refutation of the opinion of certain "theoretical" anatomists that there is no such thing as a "great transverse fissure" till artificially produced. He then slices the brain *secundum professoris artem,* and is so pleased at demonstrating the "*centrum ovale majus*" that he is not seriously disturbed at the presence of an unexpected rent in the callosum and an irregular orifice at either side. Continuing his operations, he finds the interior of the brain a mass of amorphous pulp; suspects that the names in the books have much the same significance as those of the heavenly constellations; modestly admits that he may not be sufficiently advanced to comprehend the brain, and resolves that, when this branch is undertaken again, his *armamentarium* shall consist not of a scalpel but a spoon.

§ 4. The more important of the macroscopical methods of studying the brain, pursued in the Neurologic Laboratory of Cornell University, are summarized in §§ 7–52. From the nature of the case a strictly logical sequence is impracticable; certain of them are subsequently described in detail.[†]

§ 5. *Acknowledgments.*—Did space permit, I would gladly specify the sources of such of these methods as are not original, and the points in which efficient aid has been rendered by my students, past and present, in either carrying out my own ideas or in improving upon them; the following deserve particular mention: P. A. Fish, S. H. Gage, F. L. Kilborne, B. F. Kingsbury, W. C. Krauss, B. L. Oviatt, M. J. Roberts, M. G. Schlapp, Theobald Smith, H. E. Summers, B. B. Stroud, and F. L. Washburn.

§ 6. *Order of Treatment.*—Introduction and Acknowledgments, §§ 1–6.
Summary of Principal Methods, §§ 7–52.
Preliminary Work upon Certain Animal Brains, §§ 53–59.
Removal of the Adult Human Brain, §§ 60–71.
Removing the Brains of Infants and Fetuses, §§ 72–80.
Preservative Liquids, §§ 81–90.
Injection into the Cavities and Arteries, §§ 91–115.
Dry Preparations, §§ 116–119.
Injection Mixtures, §§ 120–121.
Economics of Alcohol, §§ 122–127.
Storage and Transportation of Brains, §§ 128–131.
Dissection, §§ 132–136.
Instruments and Apparatus, §§ 137–144.
Labelling and Recording, §§ 145–151.
Methods of Representation, §§ 152–171.
Bibliography.

§ 7. Before dealing with the human brain, the various processes of removal, preservation, and dissection are practised upon the more accessible brains of the sheep (pp. 153, 173, 208, 209, 372, 374, 382) and the domestic cat (pp. 149 and 151): "*Fiat experimentum in corpore vili.*"

§ 8. Fetal and infant brains are utilized not only for what is learned from them as such (pp. 136 and 185–189), but also as preliminary to dealing with the adult organ when, as is sometimes the case, the latter is less readily procured and removed.

§ 9. Although, in most cases, the ultimate object of neurologic study is the comprehension of the structure and functions of the human brain, yet it is held to be desirable that students should understand the general pattern of the organ and recognize both the conformity of the human thereto and the degree of its departure therefrom; for this purpose are studied the brains of certain lower vertebrates, especially the green turtle (*Chelone mydas* (p. 148) and the sheep (pp. 209 and 374).[*]

§ 10. Although the pattern of the cerebral fissures of man and the other primates differs widely and perhaps irreconcilably from that of the other mammals (p. 198, § 303), yet the methods of fissural study apply equally to all, and the comparative simplicity of the fissures in dogs and especially cats renders them convenient subjects upon which to commence a difficult branch of neurology (pp. 187–206)[†]

§ 11. Still other animal brains may be found useful in the illustration of special points (*e.g.*, pp. 140, 148, 150, 170, 204, and 207); but I strongly deprecate the extent to which merely curious or startling facts of comparative anatomy are sometimes introduced into medical publications.

§ 12. Before the *detailed* study of the contours of the masses there is gained a general idea of the cavities, their connections and their circumscription.

§ 13. Skulls—which may be purchased or easily prepared under nearly all circumstances—are less esteemed than brains; the "kernel" is more highly valued than the "shell."

§ 14. The infant cranium is divided with scissors and nippers (Fig. 986), or softened by ten per cent. nitric acid so as to be cut with the knife.

§ 15. The common method of dislodging the adult calva (calvaria or skull-cap), after the circular cut with the saw, by "inserting a strong hook and giving a quick jerk," is held to be artistically brutal and anatomically futile; a second, sagittal, section is made, a little way from the meson (middle line) and the calva removed in two pieces; § 60, *E.*

§ 16. Excepting for special reasons the dura is retained until the calva is removed, and it is sometimes extracted with the brain.

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[*] The article "Anatomy" in the last edition of the Encyclopaedia Britannica (i., 876) seems to acquiesce in the present state of things as beyond remedy: "In taking the brain out of the cranial cavity this commissure [the medicommissure] is usually more or less torn through, and the cavity [diacele] is consequently enlarged."

[†] That these methods are fairly successful may be concluded from the facility with which those who practise them receive the more advanced or specialized instruction imparted at the great medical schools, and from the nature of the preparations in the museum. Yet there is hardly one of these methods that is not susceptible of change for the better; indeed, the constant effort to improve them has been a serious hindrance to the completion of this article.

[*] Were opossums as common as cats in most civilized lands the less preponderance of the cerebrum and cerebellum over other parts would warrant the general study of their brains.

[†] I desire to reiterate here the conviction expressed on several previous occasions as to the inutility of the brains of ordinary monkeys for the elucidation of human fissural problems; indeed, our present comprehension and nomenclature of cerebral elevations and depressions would be far better than they are had neither Gratiolet nor any other anatomist ever examined a monkey brain.

§ 17. The fresh brain is removed over brine (saturated and filtered), supported in it during the operation, and kept in it until its final disposition is made.

§ 18. A fresh brain in the dura is lifted by the latter and supported in liquid by attaching cords to the dural edges, the other ends of the cords being carried over the rim of the pail or other vessel and wound about hooks, or otherwise attached.

§ 19. A fresh brain deprived of its dura, if it is to be either studied from any aspect or injected into the arteries or the cavities, is supported and steadied in a pail of brine by passing under it a towel or broad strip of cloth, the ends of which are secured to the pail by hooks, tacks, or otherwise; the brain may thus be kept at any height in the brine, and rotated without touching it.

§ 20. The fresh brain is never allowed to bear its own weight or to rest upon a flat surface, but is supported in the calva or in a bowl of appropriate shape, or in a liquid of equal specific gravity, or on a bed of *ordinary* cotton.*

§ 21. The use to be made of a brain is, if possible, determined upon in advance. If only part is to be employed for a specific purpose, the rest is cut away and preservative effort concentrated upon the selected portion.†

§ 22. When the brain is to be preserved entire, especially for the elucidation of membranous attachments and the circumscription of the cavities, alcohol (or other active preservative liquid) is injected into the arteries by continuous pressure, and thus carried directly to the tissues; §§ 99 and 114.

§ 23. When a separated head is obtained the brain is sometimes hardened in place by the continuous injection of alcohol (§ 99); it shrinks somewhat, but retains its natural proportions. Such a head, medisected with a sharp saw, is instructive in many respects (Fig. 670, p. 141). Sometimes sections are made in other directions, or the calva removed as with the fresh brain (§ 60).

§ 24. For macroscopic purposes freezing is avoided, as tending to leave the mass friable.

§ 25. If a specimen is to be used especially for the elucidation or demonstration of the contours and circumscription of the cavities and the lines of attachment of membranes and plexuses, strong alcohol, or an alcoholic solution of zinc chloride, is injected into the cavities and the arteries.

§ 26. If certain portions of the cavities are in question, free access of the preservative is gained by widely opening some other region, as, *e.g.*, by cutting off a frontal, temporal, or occipital lobe.

§ 27. Unless there are special reasons to the contrary, brains are transected in the narrow region of the mesencephal (gemina or optic lobes) (Figs. 689 and 756); the cerebral and cerebellar portions are then removed separately with greater ease and less risk of laceration (§ 60, *J*). Each of these regions is medisected, if desired, more accurately than the entire brain can be, whether before or after hardening, and the two divisions of either half are subsequently apposed for study, or even attached for exhibition.

§ 28. When the mesencephalic region itself is to be preserved intact, by lifting the occipital lobes a little more the transection is made through the diencephal (thalami) (Fig. 707).

§ 29. For the study of fissures and gyres, the cerebrum (with the thalami) is commonly medisected (§ 61), and each half hardened by placing it on its mesal surface in the preservative.

§ 30. So far as possible, incisions of the brain are made in liquid or while the scalpel is irrigated; with hardened brains alcohol is used; with fresh a salt solution.

§ 31. Specimens which have become dry and distorted are immersed for a day in weak spirit (twenty-two per cent.), and then replaced in the strong alcohol.

§ 32. When [illegible] hydrocephalous cerebrum like that shown in Fig. 715) has dried, it is restored by placing on the spot a bit of absorbent cotton wet in water.

§ 33. To remove a delicate specimen from a vial, the vial is immersed in a dish of alcohol and the specimen floated out; to replace it, if the alcohol is clear, the vial is immersed and the specimen floated in; if turbid, the specimen may be transferred upon a bit of paper, a watch glass, spoon, or *upon—not between*—the points of the fine, curved forceps (Fig. 985).

§ 34. Friable specimens are infiltrated with paraffin; see the paper by W. C. Krauss (Buffalo *Medical and Surgical Journal*, November, 1888) and publications there referred to.

§ 35. Defibrillation—the tearing of brain substance in the direction of the least resistance so as to make "cleavage preparations"—is not regarded as affording conclusive evidence of tract arrangement; but it is practised in illustration of facts determined by more exact methods, microscopical, pathological, and experimental.

§ 36. For the decided maintenance or increase of the color differentiation of the two kinds of nervous tissue, alba and cinerea (p. 139, Fig. 66), specimens are immersed in, or injected with (or both), a solution of potassium dichromate (§ 85); or Müller's liquid (§ 86).

§ 37. When the color and microscopic structure are subordinate to purely morphologic considerations a choice is made between four compound liquids devised by past or present assistants in the laboratory, the zinc-glycerin (§ 88) or the zinc-formalin (§ 89) of Fish, the saline-alcohol (§ 90) or the simplified saline-alcohol (§ 90) of Stroud.

§ 38. Dry (mummified) preparations are made according to the improved method (turpentine and castor oil) of P. A. Fish (§ 117).

§ 39. When the larger vessels are to be studied, Gage's modification of Pansch's starch mixture is employed (§ 120); if the ultimate vascular supply is in question, a fine gelatin mass is used (§ 121).

§ 40. When practicable the leptomeninges (pia and arachnoid) are removed as soon as they loosen from the surface, which is commonly within two days after immersion; but this is not essential, for they may be removed at any subsequent period, with merely somewhat more care against breaking or wounding the hardened brain.

§ 41. Alcoholic brains are examined before fresh ones.

§ 42. The size and form of the cavities are maintained and the preservation of their immediate parietes is insured by injecting alcohol into them; Fig. 731.

§ 43. The forms of cavities are ascertained by making solid casts; Fig. 718.

§ 44. Encephalic fragments, and poorly preserved or distorted specimens serve for preliminary dissections, so that the perfect material may be more completely utilized.

§ 45. Before attempting to comprehend large sections, involving perhaps several parts but distantly related excepting by topographical contiguity (Fig. 732), the beginner makes dissections for the exposure of parts in their structural continuity; Figs. 681, 682, and 801.

§ 46. To facilitate discrimination of natural from artificial surfaces, especially upon permanent preparations, incisions always follow straight lines and meet at angles rather than join by curves; see Figs. 768 and 733.

§ 47. Specimens that might be injured by falling upon a hard surface from the height of even a decimetre (four inches) are held during examination over a pad of cotton or a dish of alcohol, and carried from room to room in a vessel and not in the hand.

§ 48. Embryos and delicate brain preparations are dissected under alcohol, and sometimes pinned to a piece of cork loaded with sheet-lead; see Fig. 734. Preparations including the medicommissure (Fig. 709) are supported upon cork while making and for exhibition.

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* [illegible] the use of absorbent cotton [illegible] as to and injure the ordinary cheap cotton retains its [illegible] longer.

† The city neurologist has perhaps only to decide what a brain [illegible]; but others, like the writer, may find it advantageous to [illegible] it a [illegible] memoranda of what he wishes to do with fresh brains, or heads, a half or a whole, as the case may be [illegible] among several things that might be done, and little time is lost.

§ 49. In brain dissection, as in surgery, the knife is made the last resort; blunt points and blowpipes are employed as long as possible. When cutting is to be done the aphorism of Dr. Holmes is recalled: "Let the eye go before the hand, and the mind before the eye."

§ 50. Delicacy of manipulation is cultivated and a prompt check put to all forms of anatomical Philistinism, whether in word or deed; the student is urged to practise self-control, to restrain what Hyrtl calls the "*furor secandi*," and never touch his specimen except for a good and sufficient reason. From the ecclesiastical standpoint, perhaps, the "laying on of hands" cannot be overdone, but in practical anatomy its excess is likely to prove the reverse of a blessing. These cautions are called for in respect to the dissection of muscles, etc., to which the examination of the brain is as watchmaking to the wielding of hammer and tongs.

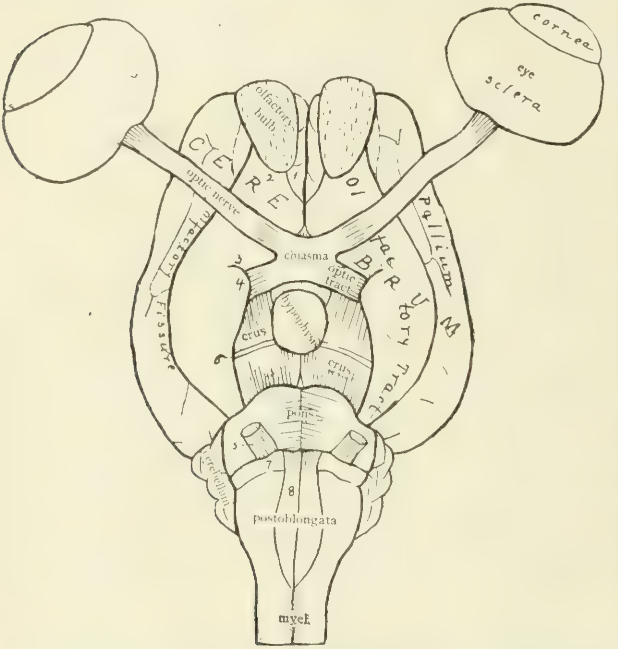

FIG. 978.—Base or Ventral Aspect of the Sheep's Brain with the Eyes Attached. Slightly enlarged. (From "Physiology Practicums.") 1, Frontal portion of pallium mesad of olfactory bulb; 2, narrow portion of olfactory tract (compare Fig. 688, p. 153); 3, precribrum ("anterior perforated space") just cephalad of the optic tract; 4, tip of temporal lobe overhanging optic tract;* 5, root of trifacial (trigeminus or fifth cranial nerve); 6, opposite the narrow band of fibres crossing the crus, called by von Gudden "tractus peduncularis transversus," cimbia by the Ass'n Amer. Anatomists; 7, trapezium, concealed in man by the overhanging margin of the pons; 8, pyramid. Compare Figs. 672 and 689, pp. 143 and 154. Most of the nerve roots and many other details are omitted.

§ 51. All specimens are numbered as soon as received (§ 146), and the essential data preserved in the form of a card catalogue (§ 151).

§ 52. From the beginning students are required to make outline drawings, accurate if not artistic, and clear rather than shaded.

§ 53. *Preliminary Work upon Animal Brains.*—I cannot too strongly emphasize the view indicated in § 7 as to the desirability of gaining from the comparatively inexpensive brains of lower mammals the manipulative dexterity and the familiarity with parts and their names so essential to making the best possible use of the precious and costly brain of man. The two particularly recommended are of the sheep and the domestic cat; but the methods of removal and dissection appropriate for the latter may be applied to the rabbit and to small dogs, while larger dogs, the pig, the calf, and cattle may be dealt with substantially as indicated for the sheep.

§ 54. *Removal of the Sheep's Brain.*—Unless already familiar with the general form and size of the organ it will be well to consult the representations of it on pp. 153, 173, 208, 209, 372, 374, 382, or a plaster cast such as may be had for a small sum at Ward's Natural History Establishment, Rochester, N. Y. The mode of extraction recommended was devised by Prof. P. A. Fish while instructor in my department in 1890, and is indicated, perhaps sufficiently, in Figs. 979 and 980. In brief, the cranium, containing the brain, is removed from the facial portion of the head by sawing in a plane coinciding with the ventral margins of the orbits and of the foramen magnum. The corners of the cranium are then sawn off and the brain exposed with nippers, beginning with the base. The nerve roots must be divided with the scissors. The dura must be divided about the hypophysis, and special pains taken to dislodge the olfactory bulbs from their fossæ (§ 60, *H*).

§ 55. *Instruments Required.*—In addition to a stout knife, coarse forceps, and coarse curved scissors, strong nippers, and a medium-sized saw, the sawing will be easier and more expeditious if the head can rest against the edge of a board or in an oblique sort of miter-box: the form of this will readily suggest itself if the operation is repeated several times.

§ 56. *Removal of the Cat's Brain.*—The following directions are condensed and modified from W. and G., pp. 423–432. The brain only is considered here and other parts are disregarded. Consult Figs. 682 and 686, pp. 149 and 151. The head is supposed to have been cut off.

A. *Instruments and Materials.*—Arthrotome or stout scalpel; coarse curved scissors and forceps; nippers of medium size.

B. *Removing the Skin.*—With arthrotome or knife, divide the dorsal skin from near the nose to the caudal free margin. Remove the skin in the easiest way by putting the connective tissue on the stretch and cutting. Note the third eyelid or plica at the mesal angle, represented in man by a vestigial fold of mucosa.

C. *Removing the Mandible.*—Dissect the temporal muscles from the side of the cranium. Divide the zygoma with the nippers, its cephalic end by pushing a point ventrad, between it and the eyeball; its caudal end by pushing a point ventrad from the temporal fossa just cephalad of the auditory meatus. The mandible may now be moved up and down so as to indicate the location of the joint; open this with the arthrotome; cut the soft parts about the mouth and throat and remove the mandible together with the larynx, esophagus, etc.

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* According to the view expressed on p. 209, § 371, the part marked 3 and the olfactory tract cephalad of it, are parts of the rhinencephal, while 4 and 6 are portions of the prosencephal.

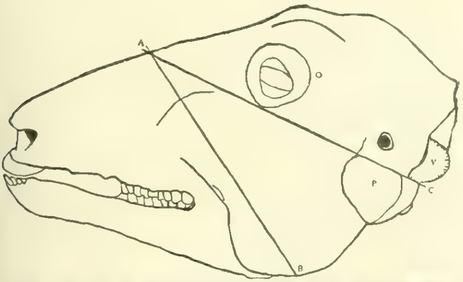

FIG. 979.—Left Side of Head of Sheep, Skinned. (From my paper, 1896, *g.*) Along the line A-B the butcher may cut with saw or cleaver so as to remove most of the face; it extends from the angle of the jaw to a point about midway between the nose and the prominence of the head between the eyes. The rest of the face is then to be separated from the cranium by sawing somewhat accurately along the line A-C, intersecting the ventral margins of the orbit O, and of the occipital condyles V. See § 54.

D. *Remove the eyes* by cutting the muscles, etc., with curved scissors. The white cylindric optic nerve at the bottom of the orbit is to be cut, not torn.

E. *Remove the cervical muscles* by cutting lengthwise at either side of the cervical spines and then dissecting off the muscles. With the nippers cut off the spines; the atlas, of course, has none. Note the occipital crest for attachment of the strong muscles.

F. *Opening the Cranium.*—Rest the head on either side. Apply the nippers at nearly right angles to the convex temporal region and "gnaw" through the cranium till the dura is reached, taking care not to plunge the points into the brain. The dura may be recognized by toughness and non-vascularity. It may adhere so closely to the bone as to come off with it, but should be left on the brain for the present if possible. Continue to expose the brain by nipping off successive fragments, by breaking rather than by direct cutting. Before crossing the meson expose the entire lateral aspect of the cerebrum and continue cautiously cephalad to the olfactory bulb.

G. *The Cerebellum.*—Expose this from the same side. Between it and the cerebrum is a bony tentorium, which may be removed without injuring the brain if the nippers are introduced sidewise for about 1 cm. between the cerebellum and the cerebrum at the meson and just above the meatus. Continue caudad by nipping the sides of the atlas and axis so as to expose a portion of the myel.

H. *The other half* of the brain is most easily exposed by passing the nippers-point between the cranium and dura at the meson, and nipping or breaking off fragments as before; but constant care will now be needed lest the fingers crush the side already exposed.

I. *Remove the maxilla* by cutting with the nippers across the spongy ethmoid region about 1 cm. cephalad of the cerebrum, and then dividing the base and sides of the maxillary bone. The olfactory bulbs may now be exposed; at the first trial one or both is almost sure to be torn or crushed.

J. *Remove the base of the cranium,* in fragments, using both nippers and coarse scissors cautiously until at about the middle of the cerebrum is seen the chiasma; try to expose the optic nerves for a few millimetres; avoid pulling upon them lest the brain be torn. The hypophysis lies just caudad and is to be saved if possible.

K. Hold the specimen, ventral side up, the brain just resting in a dish of brine. By raising the base of the cranium carefully there may be recognized successively the pairs of cranial nerves; each is to be cut with the scissors as far as possible from the brain. Continue caudad as far as the myel was exposed; then divide the myel.

L. The ventral dura has probably been removed with the base of the cranium. Remove the remainder as convenient, noting the mesal fold between the two hemicerebrums, constituting the falx, and its connection with the layers of dura between which was the bony tentorium.

§ 57. *Endymal Continuity and Celian Circumscription.*—A detailed account of these features of the mesal cavities of the human brain occurs on pp. 151–152 in connection with Fig. 687. In connection with it, and preferably as preliminary to it, the mesal aspect of the sheep's brain may be studied by the aid of Fig. 981.

§ 58. *Transections.*—Before transecting or dissecting the human brain it is well to make and study carefully transections of the sheep's brain at levels such as are indicated in Fig. 981; and at others as preferred. They are more instructive in some respects if the alba and cinerea are differentiated as by some chromic acid compound (§§ 84–86).

§ 59. *Fig. 981 illustrates:* A. The general similarity to the corresponding aspect of the human brain as shown on pp. 141, 189, and 213.

B. The slighter cranial flexure; p. 142, § 36.

C. The smaller relative size of the cerebrum, permitting the cerebellum and even the olfactory bulbs to appear in a dorsal view of the organ; p. 144, § 40.

D. The large size of the medicommissure; p. 166, § 151.

E. The distinctness of the crista in the adult sheep; p. 208, § 366.

F. The non-extension of the callosal rostrum, as a copula, to join the terma, as in man and the chimpanzee, and the consequent closure of the narrow pseudocele by the pia only; p. 184, § 223.

G. The absence, as in mammals generally, of small foliums upon the lingula; p. 160, § 119.

H. The absence, as in mammals generally, of a metapore (foramen of Magendie); p. 154, § 78.

I. The completeness of the endymal continuity or celian circumscription; p. 151, § 63.

J. The possibility of transecting several of the segments without cutting others. A–A crosses the myel; B–B the postoblongata, metencephal, overhung by the cerebellum; C–C, the epencephal (cerebellum, preoblongata, and pons); D–D, the mesencephal (crura and quad-

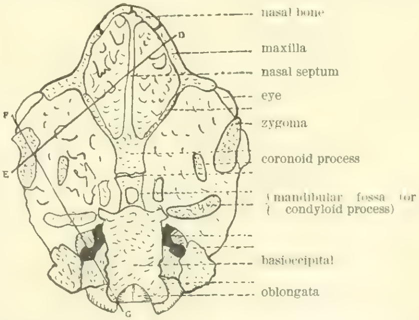

FIG. 980.—Ventral or Cut Surface of the Cranium as Separated from the Face Along the Line A–C (Fig. 979). If the parts outside the lines D–E and F–G are sawn off, the brain may be exposed by removing with the nippers the base and one or both sides of the cranium.

rigeminum); E–E, the diencephal (tuber, medicommissure, thalami, etc.), overhung by the cerebrum; F–F, the prosencephal (cerebrum) just cephalad of the chiasma G–G, the rhinencephal, at the junction of the olfactory bulb and tract (pp. 153, 173, 208, 209) overhung by the cerebrum.

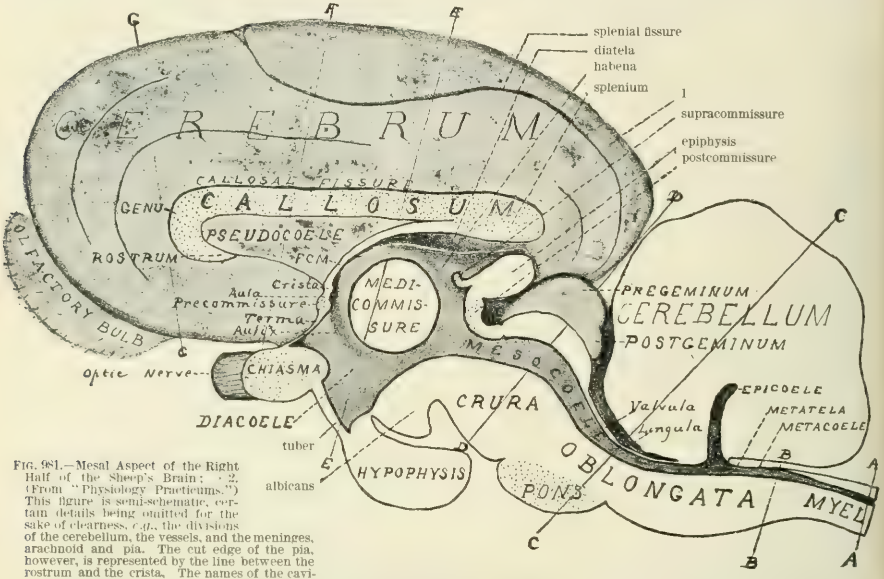

FIG. 981.—Mesal Aspect of the Right Half of the Sheep's Brain; × 2. (From "Physiology Practicums.") This figure is semi-schematic, certain details being omitted for the sake of clearness, *e.g.*, the divisions of the cerebellum, the vessels, and the meninges, arachnoid and pia. The cut edge of the pia, however, is represented by the line between the rostrum and the crista. The names of the cavities, *Diacœle*, etc., should be spelled *Diacele*, etc. The endyma lining the diatela is really continuous at each end with that of the adjacent parts. The lines *A–A* to *G–G* represent planes of instructive transections. See § 58, *J*.

§ 60. *Removing the Adult Human Brain.**—The method here recommended and described differs from those sometimes employed in three respects: First, since the brain is not to be sliced or cut into small pieces for histologic examination, but preserved entire or in large divisions for morphologic investigation and demonstration, the removal is done leisurely * and with care so as not to distort form or rupture membranous connections. Secondly, the calva (calvaria or skull-cap) is divided sagittally 1 to 2 cm. from the meson and removed in two pieces. Thirdly, the subject lies upon the belly with the head supported and steadied in the "head-rest" devised by Dr. Stroud (Figs. 982, 988).

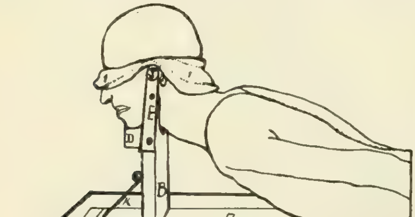

FIG. 982.—Head-Rest Devised by Stroud, in Use. (From his paper, 1900, *b*.) A, Baseboard; B, upright board; D, chin-rest; E, lateral iron bar. For details see Figs. 988–989, and §§ 142–143. 1–1, Reflected portions of the scalp.

A. *Instruments and Materials.*—In the absence of a well-equipped post-mortem case (see the article *Autopsies*) the following should be provided: Scalpel, medium size; arthrotome (Fig. 985) or a similar stout knife; syringotome (Fig. 985); probe-pointed bistoury (§ 138); coarse scissors and forceps; fine scissors and forceps; tracer; bone-chisel (§ 139); mallet or hammer; strong hook, for catching on the divided margin of the calva and dislodging it; † saw (§ 140); drill or awl or wire nail; wire and cutting pliers (p. 385); ‡ surgeon's needles and silk; absorbent cotton; common cotton; plaster of Paris; towels and Japanese napkins; scales; several pans of water and of brine, one large enough for medisection of the cerebrum. The beginner will do well to have at hand for consultation a hardened brain and a preparation of the dural folds (falx and tentorium) or models or good figures of the same (Fig. 800).

B. *Dividing the Scalp.*—Between the roots of the ears carry a cord over the highest region of the head. Wet the hair along this line over a zone 2–3 cm. wide.§ With a narrow scalpel handle or any convenient instrument part the hair along the cord so that none remains crossing the line of incision. Mark the proposed line with a soft pencil or a fine point, and remove the cord. Insert a scalpel point at the top of the head with the *edge away from the head* and cut toward either ear along the chosen line, avoiding deflections and the division of hairs. Divaricate the edges and repeat the incision if necessary so as to divide fat and connective tissue to the periosteum, or, at the sides, over the ears, to the firm fascia covering the thin (*temporalis*) muscle in that region.

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* See also the articles *Autopsies* and *Brain, Surgery of.*

* Commonly an hour and a half is allowed for the operation; but on one occasion, in an emergency, with the aid of a single assistant, Dr. Stroud removed a brain and made the head presentable for waiting friends within forty minutes.

† In the absence of one made for the purpose it may be made from stiff wire; some large pocket knives have a hook of suitable size and strength.

‡ The pliers used by the linemen of the telegraph and telephone answer admirably for both cutting and twisting.

§ This and some other details presuppose that the body may be viewed by friends or that there are other reasons for the minimum of disfigurement. Under certain circumstances they may be disregarded, although I think it well to maintain an almost esthetic and artistic attitude toward all dealings with the human brain.

C. *Reflecting the Scalp.*—Dissect up the scalp at either side and reflect it over the neck and the face to a level, if possible, a trifle lower than the first incision between the roots of the ears. Before reflecting the frontal portion it may be well to cover the face with a pad of cotton to protect the features from undue pressure.

D. *Circular Division of the Cranium.*—Tie a cord around the head just dorsad of the ears, the frontal portion passing about 15 mm. from the brows; mark this line with a pen, or cut the periosteum to the bone. If the fresh calva is to be secured in place after the extraction of the brain, leave the fibrous cephalic and caudal margins of the temporal muscles for the stitches to be taken in; otherwise these muscles may be removed entirely.

In sawing,[*] three points are to be observed: (1) The thicker frontal and occipital regions should be taken first; (2) at four places, preferably what might be called the four corners of the cranium, the bone is not to be divided completely until the calva has been sagittally divided (§ 66); (3) if the ectal features of the brain are to be preserved intact, a sectioned cranium should be consulted in order to estimate the thickness at variable points, and frequent trials should be made by pushing a point, like the probe end of the tracer, into the kerf (saw-cut) at the middle of that part of the convexity; when it can be pushed through, the sawing should proceed with care in each direction.

E. *Sagittal Division of the Calva.*—After the circular kerf has been completed, but before the calva has been loosened by the chisel,[†] carry a cord from the brows to the occiput, over the head, at about 13 mm. (half an inch) from the meson; along this line cut or mark the periosteum, and saw completely through the bone. Then, with taps of the hammer upon the chisel, sever the remaining attachments of the smaller part of the calva along the circular kerf. Sometimes that piece will come off readily; if not, introduce the spatula in the temporal region, where the bone is thin, keep its point pressed against the bone and so detach the piece; in some cases the spatula must be introduced at other points, always with the minimum amount of pressure upon the brain.

The mesal adhesions along the sinus are now directly accessible, and a sharp edge may be employed if necessary. The location of any other adhesions may commonly be inferred from what existed upon the first piece, and the removal of the larger side of the calva is completed without difficulty.

F. *The Dura.*[‡]—Unless it is desired to retain the calval dura entire the longitudinal sinus should be slit to let out the blood. Commonly, notwithstanding all precautions, the saw has cut the dura at some point. There—or at any other point—commence with the scissors or probe-pointed bistoury, and cut the dura along a line about 2 cm. from the margin of the cranium and turn it outward so as to protect the delicate brain from the sharp or rough edges of the cranium.[*] Lift the sides of the dura in turn, cutting with scissors any vessels or fibrous connections between the dura and the cerebrum; near the meson there are several veins entering the longitudinal sinus. Unless the entire calval dura is to be preserved the two sides may now be cut away along the margins of the sinus.

G. *The Falx.*—On Figs. 800, 801, and 804 (pp. 212, 213, 215) note its form and its relations to the crista galli, the tentorium, and the callosum. In a good light divaricate the frontal lobes so as to expose the narrow cephalic portion of the falx and transect it with scissors. Lift the end slowly, dividing membranous and vascular attachments as they appear; at its wide occipital end there will be need of especial care lest the traction dislocate the important relations of parts about the splenium. The wide end of the falx may now be divided along its attachment to the tentorium.

H. *Freeing the Ventral Attachments of the Cerebrum.*—These are (*a*) the entocarotid arteries ("internal carotids," Fig. 803, p. 214) and some smaller vessels and fibrous bands; (*b*) the optic nerves (Fig. 672, p. 143), the hypophysis (Fig. 689, p. 154), and the filamentary olfactory nerves passing from the ventral side of the bulb (Fig. 672, p. 143) through the cribriform plates. Unless these filaments are divided the bulbs or their tracts are likely to be torn. The head should be tilted a little so as to permit some recession of the frontal lobes. Raise these and allow a good light to enter between them and the cranial floor. With the syringotome or other small curved instrument, divide or tear the soft olfactory nerves as they enter the cribriform plate so as to free the bulbs; sometimes it may be done most easily with fine curved scissors.

The carotids are easily recognized at the sides of the chiasma and should be cut with the scissors.

The optic nerves are tough and not apt to tear, but the slender infundibulum is very easily broken; hence, before dividing the nerves, it is well to cut the dura at the margins of the hypophysial (pituitary) fossa and so dislodge the hypophysis as completely as possible. When this is accomplished divide the optic nerves close to the cranium.

Now tilt the head first to one side and then to the other so as to permit the division of some veins connecting the temporal region with the cranium.

I. The remainder of the operation will differ according as the brain is to be removed entire or in two portions, cerebral and cerebellar. For most purposes the latter is preferable, and it is so much easier that the beginner is advised to adopt it until familiarity with the parts has been gained by experience.

J. *Transecting the Mesencephal.*—Tilt the head so that the cerebrum tends to slide somewhat cephalad. Lift the occipital lobes and with the scissors cut the vessels and connective tissue and membranes just caudad of the splenium (Fig. 801) so as to expose the gemina, the dorsal lobes of the mesencephal corresponding to the crura ventrad (Figs. 707, 708). This is the narrow region connecting the wider cerebellar mass with the still wider cerebral portion, and hence called sometimes the "isthmus." With the probe-pointed bistoury or sharp, narrow scalpel cut this just caudad of the epiphysis; the knife should point almost directly at the tip of the nose if the pons is to be wholly avoided. It is sometimes well to make two cuts, one from either side, directed slightly cephalad as well as mesad so as to avoid the curved margin of the pons. The trochlearis and oculomotor nerves will probably be cut during the transection. If not, they are to be watched for and divided during the next step.

The cerebrum may now be lifted out with both hands and weighed (§ 62) or otherwise dealt with as desired (§ 61).

K. *Tentorium.*—This is to be cut, with the blunt-pointed bistoury or the coarse-curved scissors, along its attached periphery and removed entire, thus exposing the cephalic ("upper") aspect of the cerebellum (Fig. 700, p. 159). If the head is tilted a little to one side and the other, the fingers may be safely passed under the comparatively firm pons so as to lift the whole mass and expose the remaining cranial nerves (Fig. 681, p. 154). When these and the vertebral arteries are divided (Fig. 803, p. 214) the myel itself may be cut well down in the spinal canal. Lastly, after replacing the parts and tilting the head cephalad, may be divided the attachment of the arachnoid about the foramen magnum, and the mass may now be removed. It is advantageously kept entire till hardened, but the cerebrum is more easily dealt with and commonly more instructive if medisected at once.

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[*] Most of the sawing should be done by an assistant, that the chief may better accomplish the later operations.

[†] If the conditions are such that the calva must be kept entire there seems to be no other way than to remove it by pulling upon either the frontal or occipital edge with a hook as is commonly done at postmortems; but this is almost certain to tear the brain or its telas or plexuses so as to render them unsuited for morphological elucidations.

[‡] Space will not permit detailed directions for removing the brain in the dura; suffice to say that with care and patience and anatomical knowledge it may be accomplished so that only a small part of the dura is absent from the central region of the base. For the safe handling of the brain and for alinjection purposes even the dorsal half of the dura is worth saving. See pp. 171 and 213, Figs. 720 and 801.

[*] For this valuable suggestion I am indebted to Dr. Stroud.

§ 61. *Medisecting the Fresh Cerebrum.*—This is to be done with a large knife, thin and very sharp. The mass should rest in a wide dish of brine and be steadied but not actually supported by cotton at the sides. The frontal lobes are held closely together by the arachnoid along a line corresponding with the ventral (concave) margin of the falx (Figs. 800 and 801, pp. 212, 213). This arachnoid must be torn or carefully divided so as to permit the slight divarication of the hemicerebrums and the exposure of the mesal zone of the callosum, recognizable from its white color at the bottom of the intercerebral fissure.

If there are special reasons for obtaining an accurate medisection of the callosum itself or of the pseudocele (Fig. 756, p. 189) the section may begin with the callosum, preferably the genu or cephalic curvature.

Commonly, however, I have found the delicate terma and medicommissure more perfectly preserved when the cerebrum rests upon its dorsum and the chiasma is divided first. In either case the knife should be constantly irrigated.

§ 62. *Weighing the Fresh Brain.*—This may be done in any of three ways.

A. With an animal of moderate size, or a child, or a separated head, the weight of the brain represents the loss of weight of the animal, child, or head after its removal.

B. A vessel partly full of water, salt solution, or brine, is balanced upon the scales;* the brain is lifted from the liquid in which it has been, in the hollowed hands; they and the brain are rinsed with water, and the brain is transferred to the vessel on the scales. If the dura remains the weighing cannot be accurate, even by deducting its weight when removed.

C. After recording the weight required to balance the added brain, then—having first wet the hands with a liquid identical in composition with that in which the brain is immersed—remove the brain and record the loss of weight. Theoretically it should be the same as had to be added before; practically there is usually some difference, and the average of the two may be taken as representing the true weight.

§ 63. *Determining the Volume of a Brain.*—This is done, as with any other mass, in either of two ways.

A. Into a vessel of accurately known capacity pour a given volume of liquid; dip the hands in the same, and transfer to it the brain; then from a graduated vessel add enough more of the liquid to fill the first vessel. The difference between the total capacity of the vessel and the sum of the two volumes of liquid introduced represents the volume of the brain.

B. Set a vessel in a deep pan, dish, or pail. With any liquid (salt solution, water, or alcohol and water) that is lighter than the brain, fill the vessel just to the brim. Let the brain into it gradually; the overflow will represent its volume.

Obviously a combination of the two methods is most satisfactory.

§ 64. *Dividing Nerves and Vessels.*—As a rule this should be done with the scissors, not so much to avoid blunting the scalpels by contact with bone as to avoid the almost inevitable traction and breakage of delicate or important attachments.

§ 65. *Closing Divided Vessels.*—This may be desirable either to prevent the disfigurement of the body or clothing by blood, or to permit the injection of the general vascular system. In the latter case, unless the divided vertebrals and carotids can be tied or caught with *serres-fines*, the regions in which they open may be filled with plaster of Paris. In the former case, plugs of absorbent cotton may be pushed into the spinal canal and the vascular orifices at the base of the skull, and the cranium then filled firmly with the cotton so as to be compressed and crowded down by the calva.

§ 66. *Reuniting the Divided Calva.*—If necessary, at once, or at any time, the two parts of the calva may be united by wires, or even cords, passed through holes at the middle and at each end; such holes may be made with a drill, awl, or wire nail.

§ 67. *Reattaching the Calva.*—Whether reunited or not the two pieces of the calva may be secured by wires through holes at each of the four "corners" (§ 60, *D*). Further stability is gained by stitching the divided edges of the temporal fascia.

§ 68. *Sewing up the Scalp.*—A knot should be tied at the end of the silk and the needle introduced at the root of the ear, at first ecto-entad (from the surface inward), afterward ento-ectad (from within outward); the stitches not too long, and not entangling the hair. Even if the concealment of disfigurement is not essential the operation should be neatly done unless there are special reasons for unusual haste.

§ 69. *Other Methods of Removing the Adult Brain.**

§ 70. *By Removal of the Occipital Region of the Cranium.*—At the meeting of the American Neurological Association, June 22d, 1883, as reported in its Transactions, p. 84, as reprinted from the *Journal of Nervous and Mental Disease*, July, 1883, Dr. Spitzka described as follows a method which, he informs the writer, he has known to be employed by some German anatomists. The writer has not tested this method personally, but is disposed to regard it as better adapted to pathological than to anatomical purposes, and as such entitled to be considered in connection with the usual method, and with that described on pp. 789–791 of Vol. V. of the first edition of the REFERENCE HANDBOOK:

"The scalp is divided in the median line, beginning a little in front of the coronal suture, and extending down the neck. If it is desired to remove the spinal cord the incision is extended to the lumbo-sacral region. Two lateral flaps are formed in the head region, the soft parts being peeled from the dorsal aspect of the cervical vertebra and the posterior half of the skull. A circular incision is made [with the saw] in the skull, behind the ears, and completely encircling it down to the foramen magnum, care being taken not to injure the connection between the articular processes of the atlas and the occipital condyles; the posterior half of the skull is removed exactly as the calvarium ordinarily is, by taps of a chisel; sometimes a rongeur forceps suffices to complete the division near the foramen magnum. The adhesion about the lateral [and longitudinal] sinus and torcular Herophili can be readily overcome by a home-made apparatus like the knife [spatula, or round-pointed knife, curved flatwise] shown by Professor Wilder. The advantages of this method are: 1, The spinal cord and brain can be demonstrated *in continuo*; 2, the critical operation of lifting the hemispheres and gouging out or injuring the cerebellum in dividing the tentorium is obviated; 3, the nerves and arachnoidal laminæ at the base may be divided without allowing the brain to drag by its own weight. These nerves are divided from behind forward. As soon as the chiasm is divided, the skull is inclined a little, and the brain allowed to fall into the hands of the operator by its own weight, it being completely separated, except where the olfactory filaments pass through the ethmoid;

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* Some trouble will be avoided if, after the pan of liquid has been counterpoised upon the scales by an approximately equal weight, say 500 or 1,000 or 1,500 gm., the exact balancing is accomplished by removing or adding liquid with a syringe.

* See the article *Autopsies*.

but these yield readily, and I have gotten the olfactory bulb intact as often by this as the other method. The removal accomplished, the occipital segment is riveted back, and a stick of wood inserted in the spinal canal and extending to the cranial interior restores the strength to the head support, impaired by the breaking up of part of the vertebral attachments."

§ 71. The method of Féré (as briefly described in a paper "Procedé de coupe du crâne," *Soc. Anat. de Paris Bulletin*, ii., 206–207, March, 1877) is by a circular incision very low down from the eyebrows ventrad of the auditory meatus to a point between the foramen magnum and the dorsal arch of the atlas. This, if successful, would uncover the brain very fully and permit its replacement in the calva after extraction; but it seems inevitable that the petrous bones should give trouble as well as be themselves destroyed.

§ 72. *Removing the Brain from Late Fetuses, Still Borns, or Young Children.*—This is most conveniently done if the cranium and maxillary region are first cut away from the neck and mandible by cutting with coarse-curved scissors from the corners of the mouth to the nape of the neck. The mass thus obtained is compact and may stand upright in liquid.

A. Instruments and materials required. Coarse forceps; coarse-curved scissors for bone; another sharp pair for soft parts; tracer (Fig. 985); nippers (Fig. 986); large scalpel; narrow-bladed scalpel, preferably a probe-pointed bistoury; four vessels, holding about two litres each; two of water; one of preservative; one of saturated brine; if the weight of the brain is to be ascertained (§ 62) the body should be weighed before the head is removed, and there should be provided a fifth vessel of normal salt solution (15 to 2,000).

B. The scalp should be removed completely, together with the ears, and temporal muscles as far as the zygomas.

C. Cranium and dura. In young subjects these adhere closely; hence, contrary to what is recommended with adults, they should be removed together in pieces. With the tracer-point lift the united pericranium (ectal periosteum) and dura near the left margin of the prefontanel (p. 212, § 388), and with the scissors or scalpel slit the tough membrane so as to expose a little of the brain. Grasp the cut edge with the forceps and with the scissors cut out a piece including pericranium, dura, and intervening area of parietal bone. Continue in this way, using the nippers when necessary, until the entire left hemicerebrum is exposed. More and more care will be required to avoid injuring the delicate brain, either by the instruments or the cut edges of bone.

Leaving the falx undisturbed, expose the right hemicerebrum in the same way, but with even more precaution and holding the head so that the left is more or less completely supported in the brine.

D. Proceed then, *mutatis mutandis*, as directed for the adult (§ 60, G).

§ 73. *Removing the Hemicerebrums Separately.*—The following modification of the method just described has some advantages. After the exposure of the left hemicerebrum cut the veins as before. Let the head tilt to the left so as to expose the callosum. Divide it, as directed above, down to the base of the skull; then the left half of the mesencephal; then the infundibulum and optic nerve; and finally dislodge the olfactory bulb.

These last parts are then to be attended to first on the right side; the falx is easily removed, and the hemicerebrum comes out as soon as the veins are cut. The chief objection to this method is the danger of cutting the mesal aspect of one of the frontal lobes.

§ 74. When there are reasons for not mutilating the head, the removal of a child's brain is much less convenient. The body and legs should be wrapped up so as to be held and turned easily. Unless the child can be held by an assistant, it will be found convenient to let it rest in a sort of trough, like a piece of large roof-gutter; or to roll it up in a sheet of lead, which, upon pressure, will flatten so as to maintain any desired position. The tray or trough must be supported at a level with the rim of the vessel of brine, so that the head may hang over into it when desired. Needle and thread must be provided for sewing up the scalp.

§ 75. *Ventral Exposure.*—For some purposes, *e.g.*, when the organ is to be kept entire, or when the nerve-roots are to be retained, the young brain may advantageously be exposed from the ventral side; this aspect should be first studied, as shown in Figs. 672 and 806; then the base of the cranium may be nipped away, or cut with the coarse scissors; it will be well to expose one side completely first, so that any errors detected may be avoided on the other. With care the hypophysis (Figs. 689 and 708) may be retained.

This method is less applicable to adult brains, on account of the thickness of the skull; this, however, may be softened by nitric acid (§ 127).

On February 1st, 1884, the writer removed the cranium of a small monkey (*Midas*, No. 342) by means of a dental engine, working a small saw and a burr. It may be predicted that in time the work now done laboriously with saw and nippers will be accomplished more neatly and expeditiously by some apparatus like the electro-osteotome of the late Dr. M. J. Roberts (*Virginia Medical Monthly*, March, 1887).

§ 76. *Brains of the middle and later gestative periods and at term* are most useful for the comprehension of the early and simple condition of the fissures and of the order of their appearance. The best results are obtained by their prompt removal as described in §§ 72–75, and hardening with some zinc-chloride mixture (§ 89). The arterial injection of such brains rarely preserves them well, and the gyres are commonly so pressed together as to interfere with both the removal of the pia and the recognition of their relations.

§ 77. *Early Fetal Brains. Two to Four Months.*—Unless one has acquired considerable skill in manipulating such delicate objects, these should be hardened in place by one of the following methods, or by a combination of them; a five-per-cent. solution of zinc chloride in alcohol is very effective with embryo brains:

A. Injection of the preservative through the umbilical vein.

B. Immersion; if alcohol, or the above solution, is used the specimen should be suspended in it.

C. Injection of the preservative with a hypodermic syringe both into the body in general and into the cavities of the brain.* The cannula should be pushed through the scalp at the margin of the prefontanel (p. 212, § 388), obliquely latero-ventrad so as to traverse the thin parietes and enter the large frontal portion of the paracele (Figs. 667, 716, 747). The success of the injection is shown by the expansion of the opposite half of the head due to the passage of the liquid through the portas ("foramina of Monro") into the corresponding paracele.

The exposure of such brains must be done under or over alcohol; the cranium and dura must be divided together at each cut (§ 72, C). The operation is tedious, but the results are revelations, no matter how often performed; no specimens are more beautiful or instructive; see Figs. 667, 746, 748.

§ 78. Hydrocephalic brains, and those of fetuses between the second and seventh month, are alinjected in place from the aorta or other artery, and also have the more or less abundant neurolymph replaced by strong alcohol. This direct, entocelian alinjection is done as soon as possible after the arterial has begun; it is most conveniently accomplished by making a slit at one margin of the prefontanel large enough to permit the introduction of a cannula and the escape of liquid at its side. The injection need not be continuous, and, of course, should not be under pressure, but may be repeated at intervals of an hour or two.

§ 79. When a hydrocephalic or fetal brain is wanted for a special object involving the integrity of the entire cerebrum or the complete distention of the metepencephalic cavities, then the undesired region is cut away, the desired region left in the cranium, and the alcohol injected through the mesocele, continuously, in order to make up for the non-injection of the arteries.

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* So far as the writer is aware, this was first done by Professor S. H. Gage, May 17th, 1892, upon specimen 2,947.

§ 80. Removed embryo and hydrocephalous brains are relieved from pressure during hardening by inflating the cavities; Fig. 715. The buoyancy of even an adult normal brain is sometimes increased by injecting air into the arteries through a bulb syringe.

§ 81. *Preservative Liquids.*—Alcohol is a perfect preservative, but it bleaches the cinerea, and in any mixture with water strong enough to be effective the brain sinks and becomes distorted. The specific gravity of the mixture may be increased by glycerin, zinc chloride, or other heavy soluble salts (§ 82–84). Strong alcohol may be injected into the cavities and blood-vessels of the brain (§§ 91–108).

§ 82. *Alcohol and Glycerin.*—One of my most perfect and instructive fetal brains (1,820; Fig. 751, p. 187) was first placed in equal parts of alcohol and glycerin; after two days half the mixture was replaced by alcohol; after two days more alcohol alone was used, and this was renewed on the following. The mixture merits systematic trial.

§ 83. *Alcohol and Zinc Chloride.*—A five-per-cent. solution of this salt in ordinary (ninety-five-per-cent.) alcohol is very effective with embryo and fetal brains, whether by injection or immersion.

§ 84. *Ammonium Dichromate.*—Our use of this has not been sufficiently extensive for a general statement, but, at the suggestion of Professor Gage, it was employed in association with alcohol very successfully in the preparation of the specimen represented on pp. 176 and 184 (Figs. 732 and 744). In equal parts of alcohol and water the salt was dissolved in the portion of 2.5 gm. to the litre. In addition to the thorough hardening of the substance and the unusually perfect maintenance of the membranous and plexal attachments, the color differentiation was sufficient, although the subsequent prolonged preservation in alcohol alone has nearly bleached the cinerea. This salt merits further trial in various combinations.

§ 85. *Potassium Dichromate.*—This is the essential ingredient of Müller's liquid (§ 86). Dr. Stroud has determined that, at the temperature of 20° C. (68° F.), a saturated solution of potassium dichromate contains about ten per cent. of the salt; at boiling the per cent. is forty-four. His method of using it is to effect the solution rapidly in boiling water; when cool, enough water is added to float the brain just below the surface.

The specimens in this solution or in Müller's liquid should be kept in the dark, *i.e.*, in metal pans with metal covers, or in a dark room.

As soon as the brain is firm to the touch it may be soaked for a day in water and then in alcohol, at first about forty per cent., then stronger, until the alcohol ceases to be colored, after which it may be kept in alcohol of not less than eighty per cent.*

The alcohol that is so colored may be used for the same purpose with other brains, or for the storage of specimens not requiring it to be either colorless or very strong.

§ 86. *Müller's Liquid.*—This consists of two parts of potassium dichromate and one part of sodium sulphate in one hundred parts of water. Beyond increasing the buoyancy of the liquid, the sodium sulphate seems to have no special value for either microscopic or macroscopic purposes and is often omitted. Sufficient buoyancy may be attained by increasing the per cent. of the essential ingredient (§ 85).

§ 87. *The Incompatibility of Alcohol with Potassium Dichromate.*—A chemist to whom the matter was submitted states that when alcohol and potassium dichromate are mixed in any proportion the salt will be at least partially reduced, and there will also be formed, from the alcohol, various compounds, as acetic acid, acetic aldehyde, etc. These processes take place in either the light or the dark, but more rapidly in the light.

§ 88. *Zinc-Glycerin Mixture.*—After careful consideration of prior suggestions, and prolonged experimentation, P. A. Fish published (1893, p. 393; 1894, p. 101) the formula of a liquid which, "though not ideal in its effects, seems to answer the requirements of economy, fixation of the structural elements, differentiation of tissue, a minimum amount of distortion, firmness of texture, and rapidity of action.

"The formula is as follows:

Water	400 c.c.
Ninety-five-per-cent. alcohol	400 c.c.
Glycerin	250 c.c.
Zinc chloride	20 gm.
Sodium chloride	20 gm.

"The specific gravity of the mixture should be about 1.04, a little greater than that of the brain itself (1.038). The slightly greater density of the fluid is believed to be more advantageous than otherwise, since it buoys the brain until the tissue has begun to harden and can partially support its own weight. The pressure is nearly enough equal on all sides to prevent any noticeable change of form. It is recommended that the cavities of the brain be filled with the mixture (celinjected) and if practicable the blood-vessels also injected. After an immersion of about three days the specimen should be transferred to equal parts of the foregoing mixture and seventy-per-cent. alcohol for a week or more, where on account of the lesser specific gravity it should rest upon a bed of absorbent cotton; it is finally stored in ninety-per-cent. alcohol."

§ 89. *Zinc-Formalin Mixture.*—Two years later Fish published (1895, *a* and *b*) the results of two experiments with an agent then comparatively little known. Referring to the zinc-glycerin liquid he says: "Experiments with formalin (forty-per-cent. formic aldehyde) show that practically as good results may be obtained at less cost when the following mixture is employed:

Water	2,000 c.c.
Formalin	50 c.c.
Zinc chloride	15 gm.
Sodium chloride	100 gm.

The brain is left in the mixture for a week or ten days (a longer stay is not detrimental); when practicable the cavities and blood-vessels are injected with the same to insure a more uniform hardening."

Respecting the subsequent treatment Dr. Fish writes me that he recommends a course slightly different from that indicated in the papers quoted. For storage, a five-per-cent. solution of formalin, *i.e.*, 50 c.c. to 1,000 of water.* In this it may remain indefinitely if properly covered. For museum purposes it may be placed successively for a few days each in alcohol, 50, 70, 90, and 95 per cent.

§ 90. *Saline Alcohol.*—Dr. Stroud, the successor of Dr. Fish, continued experiments with the same important end in view and devised a liquid which dispenses with the irritating zinc chloride, combines the two liquid preservatives, alcohol and formalin, and overcomes the difficulty due to the slight solubility of the sodium chloride in an alcoholic mixture by employing a somewhat larger portion of another salt, sodium acetate. The formula as published in 1896 is as follows:

Sodium acetate	130 gm.
Sodium chloride	110 gm.
Formal [formalin] (forty-per-cent. formaldehyde)	20 c.c.
Alcohol (ninety-five per cent.)	460 c.c.
Water	540 c.c.

Dissolve the sodium acetate and the sodium chloride in the water. Cool and filter, then add the alcohol. With alcohol free of tax the cost is about fourteen cents per litre.

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* The specimens may be more completely decolorized by absolute alcohol (W. C. Krauss), by hydrogen peroxide (Unna, *Arch. für mikros. Anat.*, xxx., 48, 1887), or by a one-per-cent. solution of chloral hydrate (Lee, "Microtomist's Vade Mecum").

* As the formalin does not prevent the freezing of the water, cold must be guarded against.

For a human brain is required about 3 litres, *i.e.*, three times the above formula. For a sheep's brain, about 400 c.c., or half the formula.

Brains should remain in brine to soak out the blood for a time dependent on their size. They should remain in the saline alcohol for ten or fifteen days, but a longer period is not harmful. Then they may be transferred to increasing percentages of alcohol.

During the last four years there have been prepared by the saline-alcohol scores of human brains and hundreds of brains of sheep and other animals, and it has proved wholly satisfactory for macroscopic purposes, whether for dissection or permanent preservation. The structural and color distinctions between alba and cinerea are well maintained.

§ 91. Experiments are making with a saline-alcohol in which the components have a simpler ratio, and the results will be announced as soon as practicable.

§ 92. *Entocelian Injection.*—To fill with a hardening and preservative liquid cavities surrounded by flexible walls would seem to be a natural device both for the better preservation of the mass and for the maintenance of the forms and relations of the cavities.[*]

A small glass syringe may be employed for injecting preservative liquids into the brain cavities, either directly or by attaching a rubber tube and cannula.

§ 93. Seldom, if ever, excepting perhaps with very small or thin-walled specimens (*e.g.*, the brain of *Cryptobranchus* shown on p. 170, Fig. 717) is a single or momentary introduction of the preservative sufficient.

§ 94. *Continuous Injection.*—This involves, first, the elevation of the reservoir of preservative to a height (upon a shelf or at the end of a cord) sufficient to insure steady and adequate pressure; secondly, the avoidance of damage from the clogging or twisting of tubes or the overflow of the liquid that has escaped after traversing the vessels or the cavities. The various requirements may be met by simple arrangement of pinchcocks and flexible wire supports of copper or lead.

§ 95. Without conceding the existence of other natural orifices from the paraceles (lateral ventricles) (p. 171, Fig. 721), both human and animal brains present outlets for the escape of the injected liquid so as to obviate the danger of rupturing the thinner parietes under any pressure that might be required for filling the cavities. With animals the myelocele (central canal of the spinal cord) is pervious through life. With a cat, for example, where 4 cm. of the myel remained attached to the brain, alcohol injected into the diacele (third ventricle) with a syringe escaped from the myelocele in a stream 8 to 10 cm. long, although the orifice of exit was 42 mm. from the tip of the metacele and 66 from the place of injection. With human brains (excepting early stages when the myelocele would probably be sufficiently pervious) there is an ample outlet at the metapore (foramen of Magendie), (p. 154, § 78). The same is the case with apes and some monkeys. Hence the cannula, instead of fitting loosely, may be tied into the infundibulum, or made large enough to fit it closely. In the latter case the cannula may need a rubber collar to prevent its entrance so far as to lacerate the medicommissure or parietes. This precaution may be rendered superfluous by using a cannula which is bent upon itself at a right angle, in the form of a capital letter L turned one quarter way around, thus, ⌐; the shorter arm enters the orifice (for tying in the infundibulum a slight enlargement of the point is desirable); the longer rests upon the base of the brain and has attached to it the tube connected with the syringe or injection reservoir This tube should be short and slender; in the intervals of injecting it may be compressed, or plugged with a glass or cork.

§ 96. Entocelian injection, whether repeated or continuous, may be accomplished from any artificial orifice. The most favorable place is the mesocele (aqueduct) after transection of the brain; the cannula may be selected so as to fit it closely. With the cerebellar portion of the brain the metapore would serve as the outlet; with the cerebral it might be necessary to tie the infundibulum to prevent too ready escape therefrom; with a small stream at a slight elevation above the brain it is probable that any excess would be provided for by oozing along the rima.

§ 97. *Entocelian Alinjection per Luram.*—Four points are to be kept in mind: (1) The smallness of the orifice (Fig. 672), which may be enlarged, if desired, with the probe or by clipping the infundibulum shorter; (2) the general dorso-caudal direction of the passage (Fig. 687); (3) the danger of wounding the parietes, and especially the medicommissure; the cannula should therefore be short, the tube small and flexible, and the cannula pushed through a disc of rubber so as not to enter more than 1 cm.; (4) the weakness of the encephalic substance after death; hence no more pressure should be exerted than suffices to fill the cavities and cause a slight elevation of the tips of the temporal lobes. The alinjection can should be just above the level of the brain, and the cannula fit loosely in the lura so that the excess of alcohol may escape.

§ 98. *Combined Arterial and Entocelian Alinjection.*—This very effectual method of preserving a brain removed in the dura for any macroscopic purpose was employed with the specimens shown in Fig. 720. A separate reservoir must be used for the entocelian alcohol (§ 97), or the branch tube leading to the lura must be small and kept compressed so that—when the cavities are once filled—the flow will be very slight.

§ 99. *Arterial Injection of the Preservative.*—This is somewhat fully described in §§ 101–108, and is exemplified in Figs. 670 and 801. As compared with immersion it has the great advantages of rapidity and thoroughness. Any preservative may be employed, and alcohol may be used at full strength. A low temperature is needless, and even perhaps undesirable.

Barring a slight shrinkage, the natural conditions and relations are maintained.

It must be admitted, however, that sometimes the gyres are somewhat crowded against each other, so that the pial folds are less readily and safely extracted, and the fissural relations less easily determined. This applies particularly to infant brains.

§ 100. This is not the occasion for a complete history of injection processes or for the presentation of claims to originality. The transmission of preservative liquids to the tissues by a constant pressure apparatus connected with the vessels by which blood reached the parts during life is really so simple as well as effectual that it is hard to account for its comparatively infrequent suggestion and adoption. Without previous acquaintance with what had been done by others,[*] on October 7th, 1883, with the co-operation of Prof. S. H. Gage, I began upon the body of a young chimpanzee (No. 265) an alinjection of the entire body, which was prolonged for ten days and was completely successful. In November, 1885, a manatee (No. 844), 150 cm. long, was prepared in like manner. All the cats used by the general class in physiology are alinjected and packed away till wanted. Still-born children are commonly so preserved, and I recommend that, with alcohol obtained free of tax, all anatomical material in medical dissecting rooms be thus rendered innocuous, free from unpleasant odor, and fit for prolonged and thorough examination.

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[*] The method was first employed by me, as assistant to the late Prof Louis Agassiz, at Nahant, Mass., in July, 1867, for permanent preparations of great vascular sinuses in rays. Since that time it has been applied in the anatomical laboratory of Cornell University to the preparation and study of hollow organs of all kinds, stomach, cecum, heart, uterus, kidney, and brain. In 1880 I first learned that the injection of alcohol into hearts was advised in 1860 by Hyrtl, and in 1879 by Mojsisovics; the former ascribes the idea to William Hunter. I am not aware that injection of a preservative into the brain cavities was practised or suggested by any one prior to December 14th, 1881, when I employed it upon a child's brain.

[*] Arterial alinjection of the brain is named or implied by Ecker ("Cerebral Convolutions," p. 45); by Mondino (Trans. Roy. Micros. Society, 1885, p. 904); by Foster and Langley ("Pract. Physiology," p. 215); by Key and Retzius ("Studien," i., p. 104); and by the editors of the tenth edition of "Quain," vol. iii., Fig. 88. It was done in 1863 for Marshall upon a Bushman (Philos. Trans., cliv., p. 501); the dates of its performance for Flower and Owen are mislaid.

§ 101. *Location of the Arteries.*—Nearly opposite the hyoid bone, or the cephalic margin of the larynx, each common carotid divides into an ectocarotid ("external") and an entocarotid ("internal"). In the adult they differ little in size, but may be distinguished in that the ectocarotid branches at once and lies farther ventrad, while the entocarotid continues unbranched to the cranium and is accompanied by the vagus nerve.

If the neck was severed close to the head the two arteries may be dealt with independently. If at the level of the chin (as in the head shown in Fig. 670) the common carotid may be followed up between the muscles, using the tracer rather than the scalpel as much as possible. But if the neck is entire, and especially if it is to be kept so, the ectocarotid may be exposed as for surgical ligation by an incision along the ventral ("anterior") margin of the sternomastoid from the lobule of the ear. In any case the ligature must be applied close to the bifurcation of the common carotid or the superior thyroid artery may not be included. As to the vertebral artery, unless there are special reasons for not injuring the vertebræ, the transverse process may be nipped away in order to expose the vessel. The cannula is to be inserted in one, and the other tied after the arteries have been cleared. Since the two arteries unite to form the basilar it makes no difference which has the cannula, excepting that there is some convenience in placing it and the carotid cannula on the same side (Fig. 803).

§ 102. *Securing the Cannulas.*—Preferably one cannula is to be inserted in the carotid, whichever is the longer, and another in the vertebral of the same side. Each is to be very securely tied; if there is no shoulder at the cannula point, then tie also around the rubber tubing at its base. All the knots should be the so-called "surgeon's," one end of the thread being passed through twice instead of once; W. and G., Fig. 41.

§ 103. *Clearing the Vessels.*—Inject "normal salt solution" (sodium chloride, 15 gm.; water, 2 litres) into a vertebral and entocarotid artery (preferably on the same side) until the liquid runs clear from the other arteries. Place in the alinjection can about 5 litres of twenty-two-per-cent. alcohol, strained through absorbent cotton or filter paper; raise the can to about 1 metre. In connecting the tubes let all air bubbles escape. Small arteries that leak must be tied or secured with *serres-fines.* The liquid should escape in six to eight hours and be quite bloody. If the last of it is nearly free from blood, the strong alcohol may be used; if not, repeat, using half the quantity of twenty-two-per-cent.

§ 104. The strong (ninety-five-per-cent.) alcohol may now be used at the same pressure; it will pass through at a rate varying from one-third to eight-tenths of a litre per hour, and be reduced to seventy-five or eighty per cent. At the end of the third day, and perhaps earlier, the strength of the alcohol will be but little reduced; the pressure may then be lessened by lowering the can to one-half the height. By the sixth day the loss in strength may be no more than three per cent., and the discoloration insignificant. The alinjection may then be discontinued, and the head medisected (§ 109) or otherwise prepared. If desired, a colored injection mass may be thrown into the arteries of either the face (ectocarotids) or the brain (entocarotids and vertebrals), or all.

§ 105. *Turning the Head.*—There are reasons for believing that the position of a head under injection should be changed daily, in order that no one region of the cerebral surface shall be more than twenty-four hours in close contact with the cranial wall.

§ 106. *Repeated Alinjection.*—It is probable that the injection of, say, 1 litre of ninety-five-per-cent. alcohol, morning, noon, and night, for a week would harden a brain very well, but accurate experiments on this point have not been made as yet under the writer's observation. If it be tried especial care should be taken to exclude air bubbles (§ 107), to keep the brain wholly submerged or its base covered with a layer of absorbent cotton dipping into the alcohol. Such injections may be made conveniently with an ordinary rubber-bulb syringe. Repeated injection will conduce to the preservation of the celian parietes and of the plexal attachments, but is less effectual than continuous for maintaining the size and form of the cavities.

§ 107. *Exclusion of Air Bubbles during Arterial Injection.*—This is accomplished by letting the alcohol run until no bubbles appear either in the cannula or in a glass tube which is introduced near the can. The can itself should always be at a higher level than the adjoining tube, especially when it is lowered for the introduction of fresh alcohol, since bubbles are then most apt to be formed; on this account the tube should be of ample length.

§ 108. *Filtration.*—Whatever liquid is to be injected into the encephalic vessels must be carefully filtered through filtering paper, or through absorbent cotton crowded into the pipe of a funnel. This necessity applies to unused alcohol as well as to that which has already passed through tissues.

§ 109. *Medisection of the Head.**—Determine the plane of section by the following mesal points, some of which, of course, are subject to variation: (1) Interval between the central incisors in each jaw; (2) dimple at tip of nose; (3) occipital protuberance (inion); (4) myel; (5) vertebral centrum; (6) notch in cephalic margin of larynx; (7) dimple of chin; (8) middle of top of head. This last is ascertained by carrying a piece of inelastic cord over the top of the head, securing each end in an auditory meatus by crowding cotton in with it, and then finding the middle of the cord. At each mesal point make a short but deep incision. Knot one end of a cord long enough to surround the head and neck at the meson; place the knot entad of the central maxillary ("upper") incisors, and carry it over the nose, head, neck, and chin, back to the mandibular incisors, between which it may be secured by a wedge or otherwise. With the arthrotome divide the scalp, etc., along one side of the cord. Remove the cord, and at the occipital convexity (about at the line from 7 in Fig. 670) bore a hole at the meson deep enough to permit a screw to be firmly fixed.

§ 110. *Adjusting the Head.*—Place the head in the saw-box and mark with a pencil the points where the bottom and one side are in contact with the occipital region and the vertex; at these points bore a hole in the kerf large enough to admit one of the screws. Replace the head in as nearly as possible the same position; pass the spatula through the kerf above the hole in the side opposite the vertex, and adjust the head so that the end of the spatula is in the cut in the scalp. While steadied in that position pass the gimlet or awl through the hole and bore into the skull for a short distance, 3 to 5 mm.; insert the screw at this point. Repeat the operation for the occipital region. This screw should bring the head firmly against the bottom of the box. If it is necessary or desirable to remove the head in order to bore the holes, when the head is replaced the holes may be found by means of the probe end of the tracer.

§ 111. *Packing.*—Draw through the kerfs in the two sides a cord just large enough to fit tightly, and pull it down so that it coincides with the cut in the skin of the face. Pack the cotton first in the angle between the two screws; then under the neck, keeping the whole constantly adjusted by means of the thread and the kerf at the neck side of the box. When firmly packed, pour over the cotton some water until no more is absorbed.

§ 112. *Sawing.*—Remove the cord from the kerf; insert the saw so that the handle is close to the side of the box, and make the first few strokes by drawing only—then saw in the usual way; a fine stream of alcohol (any per cent. above forty-eight) should irrigate the blade during the entire operation. The back of the saw should be retained as long as possible, and screws not removed until nearly reached by the saw. Let a *gentle stream* of water flow over the sawn surfaces.

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* The following instruments and materials should be provided: Saw (§ 140); saw-box (§ 141); scalpel, the handle of which is smoothly rounded; small, narrow-bladed scalpel, arthrotome, and tracer; two screws, slender rather than thick, and 5-8 mm. longer than the thickness of the side and bottom of the saw-box; gimlet to fit the screws; short, stout awl, medium size; spool of stout saddler's thread; spatula; cotton, or cotton waste or tow or bits of cotton cloth, previously soaked in water and well squeezed, enough to fill the saw-box quite firmly; large agate pans or other suitable vessels; jars and alcohol.

§ 113. *Removal of Either Half of the Hardened Brain.**—A. Remove the falx and falcula (*falx cerebelli*). At the base divide the infundibulum close to the tuber, leaving the hypophysis to be removed separately. Note the location of the optic nerve, and divide by carrying the scalpel point latero-cephalad from the infundibulum for 1 to 2 cm., close to the dura, lest the olfactory crus be injured. Dislodge the olfactory bulb with the syringotome, turn it just over the margin of the hemicerebrum, and secure it by a small pin at either side.

B. *Transection of the Hemicerebrum.*—Recognize, if possible, the dorsal end of the central fissure, nearly dorsad of the splenium. Place a strip of paper or a cord across the hemicerebrum between points about 5 mm. caudad of the fissure and the splenium. The half-head should be in alcohol or the blade should be flooded. The vertex should be toward the operator. Note on the empty half-head the angle formed by the tentorium with the meson, or observe on the preparation in hand. Push the scalpel into the brain close to the tentorium, and with a gentle sawing movement carry its point as far as it will go; continue the movements dorsad, making sure that the broad edge of the haft of the scalpel does not bruise the brain. The completion of the transection is announced by the loosening of the occipital region. Probably the greatest difficulty will be the division of the extreme ventral part. To remove the occipital part, push the probe end of the tracer or a very narrow-bladed scalpel into the brain 10–12 mm. caudad of the section plane, near the tentorium and between two fissures; the direction should be dorso-laterad at an angle of 45°, thus nearly perpendicular to the ental surface of the cranium toward which it is pointing. Dislodge the tip of the occipital lobe by coaxing with the scalpel handle; lift the whole piece slightly with the inserted instrument; it will come out for a certain distance, and then be checked by veins, which may be divided with scissors.

C. *Mesencephalic Transection.*—From Figs. 706 and 708 note that (1) the crusta projects considerably ventrad of the mesal cut surface and (2) that the greatest width of the crus is not more than 15 mm. Hold the scalpel with the flat side at an angle of about thirty degrees with the meson, let the ink mark be at the ventral margin of the crus, and cut dorsad with sawing strokes. Place the specimen so that the depths of the incision are illuminated, and divide whatever may appear; the hemicerebrum will float up, and be readily removed if the dorsal margin be first disengaged and the prominence of the temporal lobe kept in mind.

D. *Removal of the Metepencephal.*—If the tentorium is to be retained, divide it by cutting laterad from a point just caudad of the angle between the natural, curved margin and the cut, straight margin; it is more convenient to remove it entirely. The half-head may now be placed upon a tray and supported, or held by an assistant. Crowd the edge of the round scalpel handle between the dura and the myel for 2–3 mm., beginning at whatever point a slight interval already exists, and continue the separation by gentle, yet firm pressure; special difficulties will be encountered at and near the occipital foramen, requiring perhaps the scalpel edge. Do the same for the cerebellum and pons, keeping in mind the natural curvatures of the surfaces and the locations of the larger nerves, especially the trifacial, the auditory and facial. Specific directions are hardly needed or possible for the rest of the operation.

§ 114. *Arterial Injection of a Brain in the Dura.*—If the dura has been retained, at three places upon each side, frontal, temporal, and cerebellar (or occipital if the metepencephal has been removed), pin to the dura pieces of broad, stout tape (or strips of cloth 2 to 3 cm. wide) 10 to 15 cm. long. In place of pins there may be used garment-clasps with serrated edges.

§ 115. For temporary purposes, *e.g.*, examination of the base, preparation for injection, and the single injection of a mass, etc., the brain, supported as directed in §§ 18–19, may be steadied and raised or lowered as required, within any vessel of appropriate size. If of wood, the strips of cloth may be secured by tacks (artists' "thumb tacks" are most convenient); if of glass or metal then an elastic band (*e.g.*, a rubber ring from a jar, or an elastic tape) may be stretched about the rim and the strips passed under it. The vessels must be washed out (§ 103), and the small arteries tied or secured with *serres-fines*.

§ 116. *Dry Preparations.*—The methods of making these have been considered by Fish, who has also devised improvements. The following abstracts are largely derived from his papers, 1893, 1894, and 1897.

§ 117. *Fish's Improved Castor-oil Method.*—The value of this is attested by Figs. 983 and 984, and by numerous excellent preparations in the museum of Cornell University, brains, infant limbs, and entire small animals. "The essential factor is the complete dehydration of the specimen." If originally hardened in any other than an alcoholic mixture it is placed successively for at least one week each, in fifty-per-cent. alcohol, seventy, eighty, and ninety-five per cent. If carried through too hurriedly there will be more shrinkage. It is then placed in oil of turpentine until translucent, the time required varying according to the size of the specimen. The superfluous turpentine is then allowed to drain off for a few hours and the specimen is placed in castor oil. Here it may remain indefinitely or until all the tissues are thoroughly infiltrated. Draining off the superfluous oil requires a day or two and the specimen then receives a coat of an alcoholic solution of white shellac with a camel's-hair brush. This is repeated at short intervals until the surface is firm and glossy.

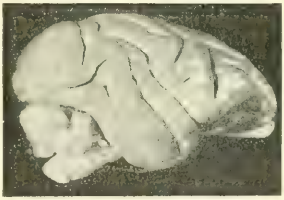

FIG. 983. Right Side of the Brain of a Monkey, *Macacus cynomolgus*. Prepared by the Castor-Oil Method. × 1. (From Fish, 1893.)

§ 118. *Laskowsky's method* is here translated from the abstract in the *Neurologisches Centralblatt*, vi., 341–342:

A. Rinse the fresh specimen in water to remove blood.

B. Place in a mixture of water, 100 parts; alcohol (ninety-five-per-cent.), 20 parts; boric acid, 5 parts; let it remain in a cool place [for at least three days; time not given].

C. Remove the pia.

D. In a saturated solution of zinc chloride in alcohol let the brain remain five or six days; the bottom of the vessel should be covered with cotton.

E. For fifteen to twenty days soak in a mixture of glycerin, 100 parts; alcohol, 20 parts; carbolic acid, 5 parts; boric acid, 5 parts.

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* The following instruments and materials should be provided: A pan to contain the half-head (about 11 × 4 in.), half full of alcohol of forty-eight to fifty-six per cent., this strength sufficing to float the separated pieces so that they may be extricated without injury (of course, water would do this, but would rapidly soften the brain); a large scalpel, the blade at least 5 cm. long and the haft 1.5 to 2 cm. more—a round-pointed "shoe knife" will serve; a medium-sized scalpel, marked with ink across the blade on each side 15 mm. from the tip; syringotome. Unless one is very familiar with the topography of the parts a model or preparation of the hemiencephal is desirable, also a hemicranium of the same side—if possible two, one dry, the other wet, with the falx, tentorium, etc. (Figs. 670, 800, 801).

F. Let it dry in the air, protected from dust.

The specimen is claimed to retain its natural volume, distinction of color, and elasticity.

§ 119. A *temporary* dry preparation for demonstrative purposes has been recommended by Lenhossek (*Anat. Anzeiger*, 1887, ii., 3–17; also *Amer. Nat.*, xxii., 858–859). A thoroughly hardened alcoholic specimen, when needed for demonstration, is dried in soft linen [or absorbent cotton], and coated with a thin layer of celloidin with a soft brush. The celloidin dries in a few minutes, forming a thin and transparent yet tough membrane. After two hours' exposure the brain will begin to shrink and should be returned to alcohol.

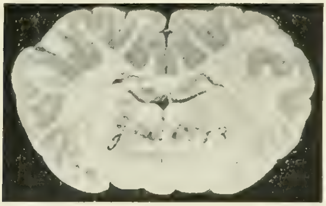

FIG. 984. Transection of the Brain of a Sheep, Prepared by the Castor-Oil Method, and Exhibiting the Differentiation of the Alba and Cinerea. × 1. (From Fish, 1893.)

§ 120. *Starch-Injection Mixture.*—Of the mixture first proposed by Pansch, the following modification has been devised by S. H. Gage and the writer:

Dry starch powder	100 c.c.
Chloral hydrate	10 gm.
Water	50 c.c.
Alcohol (ninety-five per cent.)	50 c.c.
Glycerin	25 c.c.
Coloring matter.	

After thoroughly mixing the mass it should be filtered through one or two thicknesses of wet cheese cloth. To prevent the starch from settling, the cloth should be tilted from side to side or the mass may be stirred during the filtration. If the mass is not freshly prepared for every injection, the stock mass should be filtered occasionally to remove hair or any other object that might clog the cannula.

Among the colors that are available, probably vermilion, red lead, ultramarine, Berlin blue, chrome orange, yellow, or green, is preferable.

§ 121. *A Fine, Gelatin Injection-Mass.*—The following ingredients represent about 2 litres, enough for a human brain; gelatin may be used instead of the glue, and no egg would then be needed, but it costs three or four times as much: Best clear glue, 200 gm. (about 7 ounces); carmine, 20 gm. (about 0.7 ounce); glycerin, 240 c.c. (about 8 fluidounces); alcohol, 80 c.c. (about 3 fluidounces); strong ammonia, 30 c.c. (about 1 fluidounce); acetic acid (50 per cent.), 30 c.c. (about 1 fluidounce); one egg. Grind the carmine to a paste with a little water; mix the ammonia with 250 c.c. (about 8 fluidounces) of water, add the carmine paste, and filter through filter paper. Place the glue in a clean dish and cover with cold water; after two or three hours pour off the unabsorbed water, and melt the softened glue. Beat the white of an egg well and mix it with the glue. Heat until it begins to bubble, then filter through fine flannel. Add the coloring liquid to the glue while warm. Neutralize the ammonia by stirring in the acid, a little at a time, until there is no distinct odor of either the acid or the ammonia. Until one has had considerable experience it will be necessary to close the ammonia and acid vials, let a current of air sweep over the mixture, and then determine the presence of the odor. Blue litmus paper may be used until there is no distinct coloration of the band formed by absorption just above the line made by the mass itself. Mix the alcohol and glycerin and add to the mass. Unless, as with a freshly killed animal, the injection is made before the body has cooled, the part to be injected must be heated, in water, to 40° C. (about 105° F.).

§ 122. *Alcohol.*—Unless otherwise specified, the alcohol mentioned in this article is of the usual strength, ninety-five per cent. The admixture of alcohol with water in the following proportions gives various percentages: Alcohol 6, water 1 = 84 per cent.; 5 : 1 = 82; 4 : 1 = 78; 3 : 1 = 75; 2 : 1 = 67; 1.5 : 1 = 62; 1.25 : 1 = 60; 1.1 : 1 = 55; 1 : 1 = 48; 1 : 1.25 = 45; 1 : 1.5 = 42; 1 : 2 = 35; 1 : 3 = 30; 1 : 4 = 22; 1 : 5 = 18.

§ 123. *Obtaining Alcohol Free of Tax for Scientific Purposes.*—Blank forms for this and all the information required may be obtained from collectors or deputy collectors of United States Revenue or from manufacturers of alcohol. See U. S. Revised Statutes, Section 3297, Treasury Circulars of July 2d, 1886, and March 26th, 1889, and New York *Medical Journal*, March 30th, 1889.

§ 124. The surface of a fresh brain is never exposed to strong alcohol without a previous wetting with salt solution or water.

§ 125. The alcohol in which brains are stored is maintained at *not less than eighty-two per cent.* upon the alcoömeter scale of Tralles (§ 126). Weaker alcohol is employed for the immersion of fresh brains, for soaking out the dark coloring matter from brains that have been hardened in Müller's liquid, or for the preservation of other specimens requiring a less strength.*

§ 126. *Alcoömeter* (*Alcoholometer*).—This form of hydrometer, for determining the percentage of alcohol in a given liquid, should be marked with Tralles' scale. With the slender jar for containing the tested liquid, the cost is about $2.50, but its employment is to be recommended upon the ground of ultimate saving of alcohol.

§ 127. *Dilute Nitric Acid.*—This is useful for softening the cranium of infants or small animals so as to permit cutting with knife or scissors. A ten-per-cent. solution is sufficient. Ordinary commercial acid is about sixty per cent.; the desired reduction is accomplished by adding five parts of water to one of the acid by weight, or seven of water by volume. The specific gravity of the mixture is about 1.057. In any mixture the per cent. of acid may be determined by the method recommended by Fresenius, second American edition, p. 688.

§ 128. *Storage of Hemicerebrums.*—The human hemicerebrum is a somewhat bulky mass, and may occupy a six-by-eight-inch Whitall & Tatum jar (Fig. 990). Sometimes both halves of a cerebrum may be accommodated, although the undivided cerebrum or entire brain commonly requires a nine-by-eight-inch jar.

The most favorable method of storing several hemicerebrums is in jars nine inches in diameter and of any desired height. The specimens are set in tiers of three, their dorsal convexities against the sides of the jar. Successive tiers are so placed that a hemicerebrum rests upon the interval between two below. There will be a central vacancy which, if the jar is to be transported, may be filled with absorbent cotton; the alcohol (ninety-five per cent.) should be introduced last.

§ 129. *Transportation of Fresh Brains.* — Without affirming the impossibility of transporting a fresh brain safely in a bed of cotton or other soft material, I have found it much better to employ a liquid of approximately its own specific gravity, about 1.04. The most easily prepared is brine, nearly saturated. Nor is it best to put in cotton or other material. The brain should just float, without pressing upon the bottom of the pail or rising above the surface. The cover of the pail may be secured with strips of surgeon's plaster.

In cool weather a journey of two or three days may be safely accomplished. In warm weather, if the brain is well cooled in advance and the smaller pail set in a larger and surrounded with rather large pieces of ice, a day's journey may be accomplished safely. Such open packages should be plainly marked "Specimens of Natural History. This side up with care." (See also p. 206.)

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* The "economics of alcohol" is treated somewhat fully in W. & G., pp. 111–130.

§ 130. *Other Liquids.*—It must be remembered that while brine supports the brain and thus averts mechanical injury, and while it retards decomposition, it is not strictly a preservative of nervous tissue. Hence, especially if the weather is warm or transportation is to occupy more than a few hours, it is well to place the brain at once in a liquid which will not only support but preserve it. Several such are enumerated in §§ 81–90.

§ 131. *Transportation of Hardened Brains.*—Already hardened brains may be transported either in a small pail of alcohol with cotton as a padding; or in a soldered box; or in a jar (the rubber of which must then be well covered with vaseline *to be afterward removed*);* or simply wrapped in alcoholic cotton covered with paper and oiled silk, or rubber sheeting, and packed in a box with soft material. Glass and metal packages are always enclosed in wood † or corrugated pasteboard.

§ 132. *Removal of the Pia.*—The early removal of the pia ‡ has been already recommended, § 40. I have seen some otherwise valuable cerebrums materially injured by faulty methods, and a few suggestions are here offered.

A. Begin with the central fissure, if it can be recognized, and at about the middle of its length. Apply the coarse forceps so that their approaching points move in the direction of the length of the fissure; pinch up a fold of pia; with the scissors snip at either side of the fold so as to raise it a little; then carry the forceps, held in the same way, more deeply into the fissure, not more than 1 cm. deep, and attempt to draw out the intrafissural fold of pia. If successful, continue to pull *lengthwise of the fissure*, cutting the pia at either side whenever necessary.

B. Most of the other fissures may be dealt with in the same way; but some, notably the occipital and calcarine, are very deep, and arteries traverse them which must usually be cut more than once.

C. The Sylvian fissure is not only deep, but spreads laterad over the insula, and there are several arteries. Rather than run the risk of tearing the adjoining gyres it is better to remove only so much pia as easily separates, leaving the rest and the arteries until one of the operculums can be cut off and afterward replaced.

D. While removing the pia or studying the lateral fissures of young or fetal brains, breaking is avoided and divarication of the gyres facilitated if the hemicerebrum is placed on its meson on a piece of thick Manila paper (such as is used for the portfolios), which is sufficiently firm to support the organ and yet yields so as to permit the exposure of the fissural depths. When the mesal surface is studied the specimen should rest in a thick bed of cotton.

§ 133. *Prevention of Drying.*—The strong alcohol in which brains are preserved (eighty per cent. and upward) evaporates rapidly while the brain is exposed, as in examination or dissection. It may be dipped in the alcohol occasionally, or—which is preferable with delicate specimens—the alcohol may be allowed to drip gently upon it from a pledget of absorbent cotton. When a specimen only partly submerged in alcohol has to be left for a short time, drying may be prevented by covering it with a thin layer of cotton, one end of which dips into the liquid.

§ 134. *Dissection of the Brain.*—As commonly practised this contrasts strongly with the examination of the rest of the body. With the latter dissection is universal, and sections are seldom made or even studied;§ but with the former, sections, macroscopic or microscopic, are the rule, and dissections, careful, prolonged, and thorough, are nearly unknown in medical schools. Like the preponderance of osteology over neurology, the difference is due to the "nature of things"; but like many other natural conditions it may need modification.

The advantages of sections for surgical, pathological, and regional study are obvious; they are easily made, even with the fresh adult human brain, especially by means of the apparatus devised by Professor Dalton.* If the human brain were like that of the frog or opossum, with the several segments of approximately equal size, and nearly upon the same plane, the common method would be more appropriate for macroscopic study. But, in view of the extreme cranial flexure and the overlapping of certain segments by others, the objections to sections are as follows:

1. They present plane surfaces which do not naturally exist in the brain.
2. They are almost invariably oblique with respect to the axis.
3. They commonly include more than one encephalic segment, and are, therefore, so far as the beginner is concerned, apt to be more confusing than instructive.
4. They present the parts in contiguity rather than continuity.†

The foregoing objections apply to all sections. A macroscopic section, especially of a brain which has had the cavities alinjected, presents the advantage of exhibiting in perspective enough of the natural contours of parts to facilitate their recognition and comparison.

Admitting, then, that sections have their uses, what is urged is, not that section-making be practised less, but dissection more.

§ 135. *Preliminary Dissection of Alcoholic Brains.*—I am yearly more convinced of its importance on four grounds:

A. The brain is a complex organ and at the best perplexing; the simpler features of form, location, and relation to cavities are morphological, while color, like histological composition, has a physiological significance.

B. The fresh brain is less easy to dissect neatly, and requires constant support against its own weight, whereas the alcoholic may be held in any position and carved like cheese.

C. The beginner should advance cautiously, and therefore slowly, and the medical student is especially liable to interruption. The fresh brain remains fresh but a very short time, while the alcoholic is in itself imperishable. Leisure means not only more careful dissection, but also the taking of notes and the making of drawings; hence all the arguments which I have advanced (W. and G., pp. 55, 56) in favor of preliminary anatomical work upon a small animal, which may be kept in alcohol for an indefinite time at slight expense, apply to all alcoholic brains in general, and to those of moderate size in particular.

D. After repeated dissection of alcoholic preparations, the anatomist is better qualified to manipulate the fresh brain and to appreciate its beauty. The last word is used advisedly, for, however unattractive may be "subjects" and pathological "cases," the most exacting artistic sense can hardly fail of satisfaction with the soft white and gray and pink of the newly extracted brain. Resting securely in its calva, for him who has been disciplined by prolonged experience with the "pickled" organ, there are few more attractive, stimulating, or nourishing articles of intellectual pabulum than a fresh brain "upon the half shell."

§ 136. *Dissection.*—Whether fresh or hardened, I believe the first step should be to slice off the dorsal parts of the cerebrum to near the level of the callosum and the next the exposure of the paraceles as described in connection with Fig. 735.

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* Vaseline will prevent the leakage of alcohol or other liquid; but, like oils and grease, it disintegrates rubber; hence the rubber rings should be thoroughly cleansed from it after use.

† For mailing alcoholic specimens contained in vials of not over four-ounce capacity, see circular of the Denison Manufacturing Company, New York City, as to "liquid mailing boxes." See also a paper by F. T. Gordon, *Medical Record*, lvii., 696.

‡ It is understood that this includes the arachnoid, which on most parts of the cerebrum adheres closely to the pia; Fig. 796

§ Notwithstanding the example and opportunity offered by works like Braune's "Atlas of Topographical Anatomy" and Dwight's "Frozen Sections of a Child" and "Anatomy of the Head."

* "Topographical Anatomy of the Brain," Philadelphia, 1885, vol. i., pp. 4–10; abstracts in New York *Med. Record*, February 15th, 1879; July 31st, 1880.

† Solly's vigorous reprobation refers particularly to horizontal slicing: "It is unfortunate indeed that candidates for the medical diploma are still very generally required to describe the appearances presented by the brain dissected, or rather destroyed, by the old method of slicing—a method most unphilosophical in its conception, and totally inadequate to impart any real information in regard to the structure of the brain."

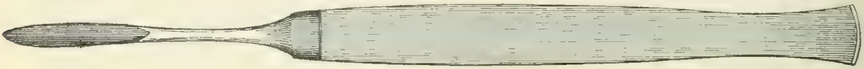
The occipital lobes may then be cut off opposite the splenium and one or both medicornua followed to the tip of the temporal lobe.

The next object should be to remove the overlapping parts of the cerebrum from the subjacent diencephal (and so much as may remain of the other segments) so as to obtain a view of the ventral aspect of the splenium and fornix. These may be transected a little caudad of the portas.

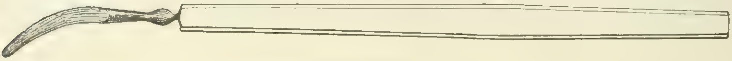
There will then appear the velum, with the epiphysis. If the velum be lifted carefully there will be recognized the attachments along the dorso-mesal curvature of the thalami which are commonly ignored but insisted upon in Fig. 732.

A transection through the portas will give a view of their boundaries, of the cephalic aspect of the medicommissure, and of the caudal surface of the fornix and the precommissure; most of the other features are more easily examined upon the mesal aspect of the medisected brain.

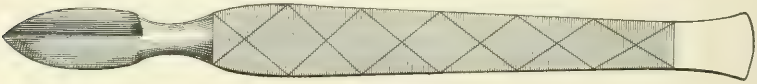
Somewhat full directions for dissection are given by Edinger. Complete directions are desirable, accompanied by figures indicating the appearances presented at each



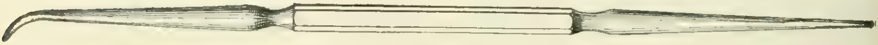
Blunt-Pointed Scalpel.



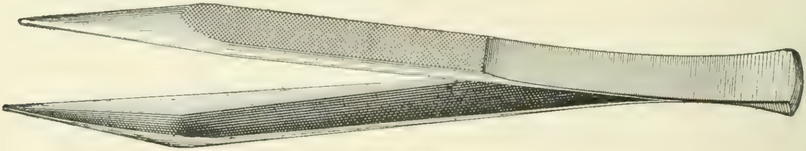
Syringotome.



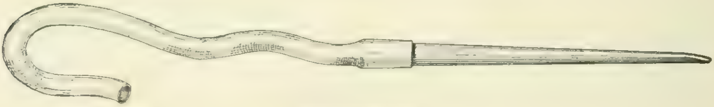
Arthrotome.



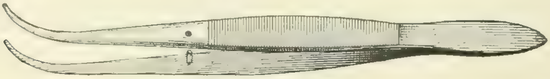
Tracer.



Coarse Forceps.



Flexible Blowpipe.



Fine Curved Forceps.

FIG. 985. Some of the Instruments Useful in the Removal or Dissection of the Brain. All of actual size. (From "Anatomical Technology.") The two upper are eye-knives; the syringotome is commonly called *canaliculus knife*; it is of great use for exploring orifices, the porta ("foramen of Monro") and the metapore ("foramen of Magendie"), and for dealing with membranes and plexuses where a point or a prominent edge might do injury; it has been my favorite instrument since 1866. The tracer may be employed sometimes in place of the more costly syringotome, but its chief use is in isolating nerves and vessels by tearing the connective tissue. Most forceps are too stiff and soon tire the hand or hinder delicacy of manipulation; the coarse "Coxeter" forceps represented have the blades excavated so as to be lighter than usual. The flexible blowpipe is most readily made by attaching to a piece of rubber tubing, 30 to 40 cm. long, the smaller half of the metal blowpipe commonly sold with dissecting instruments. The length of the tube enables the object inflated to be held at a convenient distance from the eye; since inflation is temporary injection, the advantages of witnessing the effects are obvious. A larger volume of air may be utilized by using the larger half of the metal pipe, and glass cannulas of any size may be employed. The arthrotome has the handle continuous with the blade, and one edge of the blade is rounded, excepting near the tip; it is practically a cartilage knife. The fine curved forceps represented have the points simply serrated; but for the removal of the pia from the brain surfaces, and especially from the depths of fissures, a pair with interlocking teeth, like those of artery forceps, will be found very useful.

stage, such as I have framed for the brains of the cat (W. and G.) and sheep ("Physiology Practicums").

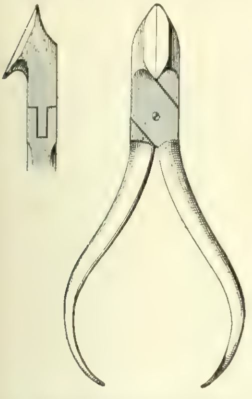


FIG. 986.—Diagonal Side-Cutting Nippers. A little less than actual size. From "Anatomical Technology." This is the smallest size of the English make (Stubs'), and for most purposes should have the handles lengthened by pieces brazed on. The German and Swiss instruments (for sale by large hardware dealers) are less highly finished and costly, but answer nearly as well. Of these, seven sizes are made, ranging in length from 10-20 cm. (4-8 inches), and in price from 60c. to $1.50. Surgical bone forceps and dental wedge-cutters have a spring between the handles and are more expensive. The nippers are most serviceable for removing the calva of infants and fetuses and of small animals. In use they must cut or squarely break the bone; the pulling and tearing to which one naturally resorts will inevitably tear the brain or its meninges.

§ 137. *Instruments.*—The instruments employed in the removal or dissection of the brain (§§ 50, 136) should, as a rule, be reserved for that purpose. If used in ordinary dissection their points and edges should be attended to without delay. Some of the less familiar instruments are shown in Fig. 985.

§ 138. *Probe-Pointed Curved Bistoury.*—This is practically a longer and stronger syringotome (Fig. 985), the cutting edge being about 5 cm. (2 in.) long, ending in a probe point. The curve is less than that of the syringotome. It replaces the latter in the dissection of the entire human brain, and it is particularly applicable to transecting the brain through the mesencephal, to tracing the medicornu, and to slitting the arachnoid in following the Sylvian or other deep fissures.

§ 139. Besides the instruments shown in Figs. 985 to 987, the following, more familiar, are indispensable: Scalpels of three sizes: large for sections; medium for ordinary dissection; small ("Charrière") for finer dissection. Scissors, curved flatwise, three sizes. A hand lens, tripod magnifier or "linen tester." A bone-chisel, or ordinary chisel of moderate width, or even a screw-driver sharpened slightly. A syringe, metal, or rubber bulb. Absorbent cotton; if common cotton is used it must be first thoroughly wet in alcohol or water. Cannulas, rubber tubing, and the **Y**-tubes or **T**-tubes for branching of injection tubes may be had of dealers. The smaller end of a straight "medicine dropper" makes a fair cannula.

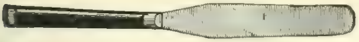


FIG. 987.—Steel-Handled Spatula. × 0.5. (From catalogue of Whitall, Tatum & Co.) This (or a palette-knife, or round-ended shoe-knife, ground thin so as to be flexible) is indispensable for detaching the dura when the calva is to be removed.

The methods of making and securing cannulas, and of making injections, are detailed in "Anatomical Technology," pp. 137–148. Cheap and efficient pinch-cocks may be had in the form of the wooden, spring clothes-pin, which may be variously attached to the wire cranes or used independently upon the tubes.

§ 140. *Saws.*—There is no special advantage of the expensive surgical or anatomical saw over the ordinary carpenter's instrument; it should be kept sharp and well-set, and used for no other purpose. For dividing the cranium any small saw will answer, but the edge should be rather wide so as to make a broad kerf. For medisection of the head, however, the saw should be very large, fine toothed, thin (*i.e.*, make a narrow kerf), have a removable back, and be very sharp and free from rust.

§ 141. *Saw-Box.*—This (which might be called a macrotome) is a coverless box made of boards about 2.5 cm. (1 in.) thick, and with the following inside dimensions: length, 30 cm. (12 in.); height, at middle, 25 cm. (10 in.) sloping to 15 cm. (6 in.) at the ends; width, according to the length of the neck attached to the head, 25-40 cm. All the parts must be accurately squared and put together with screws. The sides should go outside the bottom and ends, and the bottom have a cleat at each end. Each side is to be divided squarely at the middle of its length by a saw of the same thickness as that with which the head is to be cut; the bottom also is to be sawn to the depth of 1-2 mm. When finished the box should be thoroughly oiled, inside and out, with linseed or olive oil, to prevent warping when it is wet.

§ 142. *Head-Rest for the Removal of the Brain.*—The following description and figures (988, 989, and 982) are from the paper of B. B. Stroud (1900, *b*) who devoted much time to the device. The apparatus was shown at the meeting of the Association of American Anatomists in Washington, May 2d, 1900.

"This apparatus was devised for the purpose of holding the head firmly with the base of the cranium horizontal. This enables the base of the skull to serve as a shallow tray in which the brain is supported during its removal. The subject lies upon the belly, being supported by adjustable clamps fitting into the auditory meatuses, and the head naturally assumes a position in which the long axis of the cerebrum is nearly horizontal. Repeated trials in the neurological laboratory at Cornell University this spring have shown that with a maximum of convenience to the operator there is a minimum of danger of rupturing the cranial nerves and certain delicate structures of the brain itself, which are frequently torn when the usual methods are employed. Fig. 988 shows a general view of the apparatus. Fig. 989 shows details of construction. In Fig. 982 it is represented in use.

"The device consists of a baseboard *A* to which is attached at right angles a second board *B*. Both are of seven-eighths-inch oak. Professor Wilder suggested that the upright board should be hinged to the base for con-

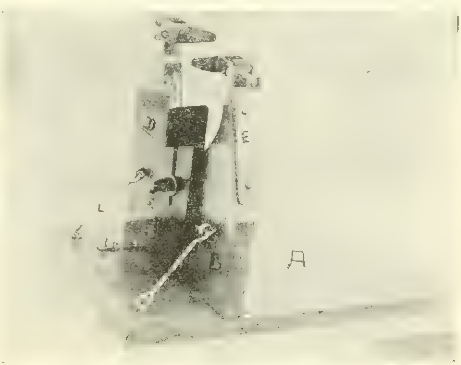


FIG. 988.—Head-Rest for the Removal of the Brain. Devised by B. B. Stroud. A, Baseboard; B, upright board, hinged to A and secured by hooks. (From Stroud's paper, 1900, *b*; see Figs. 982 and 989.)

venience in storage and transportation. This is a very valuable improvement.

"The upright *B*—Figs. 988 and 989, A—has a middle emargination and the sides are cut at an angle as shown in Fig. 989, A. The chin-rest *D* is hollowed upon the top to fit the chin. It slides in a shallow groove 0.5 cm. (¼ in.) deep, cut in *B*, and is adjustable by means of the thumbscrew. The two lateral bars *E* are of iron. They project 3.5 cm. (1¼ in.) above the board *B*, and serve to support the two jaws *F* and *G*.

"The two clamps for grasping the head, Fig. 982, shown in detail in Fig. 989, B, consist of the jaw *F*, the guides *I*, and the screw *J*, which pierces *F* in the form of a spike *H*, 2 cm. (¾ in.) long, to enter the auditory meatus. A flat head *J*, Fig. 989, *B*, is more convenient for turning the screw than the round milled head shown in Fig. 988. The jaw *F* is bent flatwise to fit the curve of the skull and grasp it dorsad of (posterior to) the mastoid process. The other end is curved downward, to fit under the zygoma and thus hold the head more firmly. The guides *I* are made from one piece of steel bent in the form of a rectangle and made to fit very closely to the top of the side iron *E*. They and the curved form of *F* prevent a disagreeable rocking motion of the head. *F* is firmly riveted to *I* by means of four double-headed rivets. The upright *B* is held in position by the two hooks *K* and *L*." *

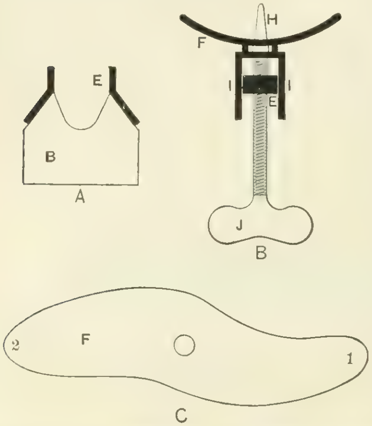


FIG. 989. Portions of the Head-Rest. A, the upright board, with its side irons, *E*. B, One of the two clamps for grasping the head. C, improved form of the jaw-piece, *F*.

§ 143. *Agate-Ware Pans.*—The brain anatomist will find most convenient, and in the end most economical, one or two "nests" of iron pans, "enamelled," so as not to rust, with plates of the same for covers. For the largest size (11 × 4 in.) covers of glass or metal must be provided; this size will accommodate a half head.

§ 144. Butter jars, 10 × 10 cm., or 10 × 20 cm., with tin screw-cap, parchment lined, are sold by the Excelsior Package Co., 49 Warren Street, New York. They are very convenient for temporary storage or for transportation.

§ 145. *Labelling Specimens.*—Much of the real value of a specimen depends upon its identification as being a certain part of a certain brain, taken from an individual of a certain age, sex, and nationality, and preserved in a certain way. Even if the possessor has so few specimens that he feels sure of remembering the entire history of each, his death would abolish the source of information. I have observed surprising instances of carelessness in this regard, even upon the part of some who should set an example of scientific accuracy.

Were the specimen never to be removed from the jar in which it alone is kept, the object could be accomplished by inserting the label in the jar or attaching it thereto; but this is rarely an adequate precaution, neither is it often possible to state all the desirable data upon a label attached to the specimen itself. The most satisfactory plan tried is *the adoption of a serial number for each brain.*

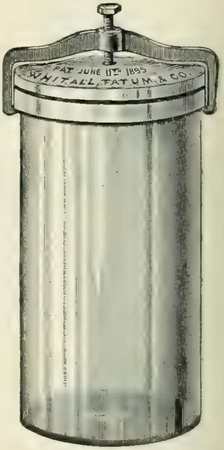


FIG. 990.—Specimen Jar, with Glass Top, Rubber Ring, and Clamp. (Made by Whitall, Tatum & Co., New York.) Fourteen sizes are made, ranging from three to nine inches in diameter, and of various lengths. The size here shown is 6 × 12, and will receive a half brain or the two halves of a medisected cerebrum; for undivided brains and for medisected heads the size 9 × 8 suffices. These two sizes cost, respectively, $10 and $18 a dozen. The prices given in the catalogue are subject to a discount of fifty per cent.

FIG. 991. — Landenberger's Specimen Jars. These have a rubber ring and a glass top retained by a wire. The smaller size is 3 × 3 in., capacity 6 oz. (180 c.c.); the larger, 3 × 4 (high), capacity 10 oz. (300 c.c.). 25 N. Thirteenth Street, Philadelphia.

§ 146. *All Specimens are Numbered.*—As soon as received every brain is assigned a number which permanently designates it and all parts into which it may at any time be divided; the same number pertains to all notes, photographs, and drawings of it.

§ 147. Sometimes, as with entire brains or half-brains, it is possible to attach with a cord a metal (sheet block tin, stamped) number. But commonly the numbers are written with India ink * upon bits of parchment and attached by small (ribbon) pins. †

§ 148. For purposes of dissection, photographing, or drawing it may sometimes be necessary to remove the label, but ordinarily it should be affixed to some other region, so that there may be no possibility of misplacement.

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* For the convenience of those who may desire to construct the head-rest the detailed specifications are here reproduced: *A* and *B* are made of ⅞-in. oak. *A* is 30 x 40 cm. (12 x 18 in.). *B* is 30 x 26 cm. (12 x 10¼ in.). It is cut as indicated in Fig. 989, A. The middle cut is 15 x 13 cm. (6 x 5 in.). The front side contains a groove ⅛ in. deep and 3⅝ in. wide to receive the chin support *D*. *D* is of oak 5 x 9 x 17 cm. (2 x 3½ x 6¾ in.). The top is hollowed out to fit the chin 4.5 cm. One and seven-eighths in. from the top it is cut down so as to be only .5 in. thick. There is a slot in the middle to accommodate a set screw for fastening it at the different heights. *E* is an iron bar, 17 x 2 x 1 cm. (6¾ x ¾ x ⅜ in.), and is bent at a point 3.5 cm (1½ in.) from the top so as to be perpendicular to the base *A*. *F* is of $\frac{3}{16}$ in. steel, 9 x 3 cm. (3¼ x 1¼ in.) and formed as shown in Fig. 989, B and C: 1 is the front end shaped so as to fit under the zygoma; 2 is the rear end and grasps the temporo-occipital bone dorsad of the mastoid process. The clamps *I* are made of ⅜-in. steel 12 x 2.5 cm. (4¾ x 1 in.) and bent as shown in Fig. 989, B. The screw *J* operates the jaw *F*. It is made of $\frac{5}{16}$-in. iron 4 in. long. It has a shoulder which is received between *F* and *I*. The spike *H* projects one inch beyond *F* to be inserted into the auditory meatus. A flat head is more convenient than the round one shown in Fig. 988. All sharp edges should be rounded and smoothed to avoid accidental injury to the operator's hands.

* Good pencil marks last a long time in alcohol, but ordinary black ink is speedily washed out.

† In time ordinary pins corrode and may break the brain substance when withdrawn; pins of aluminum or silver should be available at a moderate cost.

§ 149. *Distinctive Labels.*—The ready recognition of cerebrums belonging to groups may be provided for as follows:

A. The sexes are distinguished by using quadrangular labels for males and circular ones for females.

B. Presumed normal white brains have white labels; Africans (of all shades), gray; murderers and other criminals, red; insane and idiots, blue.

§ 150. *Immediate Records are Made.*—No one's memory is conceded to be infallible. All data concerning a brain not obtainable from the specimen itself are recorded without delay under the number assigned to it; *e.g.*, the sex, age, known, believed or estimated, race, known or supposed weight when fresh, donor, mode of initial preservation, weight or bodily condition of the individual, and his character or mental state.

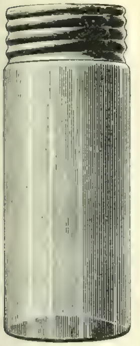

FIG. 992. Tall, Round, Screw-Capped Jar, with Nickel-Plated Caps, Cork-Lined. Three sizes, viz.: four ounces, eight ounces, and sixteen ounces. (Whitall, Tatum & Co., New York.) Answers well for dry or non-volatile contents or for the temporary storage of alcoholic specimens.

§ 151. *Card Catalogue.*—The basis of the records of each brain is a card bearing the number of the specimen at an upper corner. Upon the face of the card are written the data mentioned in § 150; also, or continued upon the back, the numbers of negatives, and references to published figures or descriptions; suggestions of points to be elucidated are commonly put on paper slips.*

§ 152. Drawing is insisted upon.† These drawings should be, primarily at least, in outline only; shading, like charity, "covereth a multitude of sins."

§ 153. In beginning the study of a difficult region, the student is advised to determine at once some prominent feature as a landmark, as a "base," so to speak, "of intellectual supplies," from which he may explore in any direction, and to which he may return when doubts arise.

§ 154. No observation involving either complex manipulation or novel results is published until it has been submitted to at least one other trained observer.

§ 155. It is freely admitted that rarely, if ever, is all possible information gained from a specimen at one examination or by a single observer; hence specimens are preserved.‡

§ 156. *Methods of Representing the Brain.*—The following considerations and suggestions apply more or less directly to all natural history illustrations, but with especial force to the human brain, on account of its softness when fresh, the difficulty of preserving it, the great size of the entire organ, the minuteness of certain portions, the large number of recognizable parts within a small area, the continuity of all, the contiguity of some which are otherwise associated but remotely, the intermixture of two differently colored substances, the complicated relations of the meninges to each other, to the vessels, and to the cavities, and the preponderance of curved and oblique contours over straight lines and planes.

§ 157. *Importance of Orientation.*—With all organs, but especially with the brain, it is essential that the location of the region represented be easily recognized; otherwise details may be unappreciated or even misapprehended. So far as possible, therefore, less familiar parts should be accompanied by such as are unmistakable. It might seem that useless expense was incurred by the publishers of Bourgery and Jacob's magnificent plates in the introduction of faces artistically drawn and colored; but even the expert neurologist is guided in the comprehension of the relative position of brain parts by reference to the apparently superfluous facial outlines.

§ 158. *Enlargement of Complex Regions.*—It often happens that the same section or dissection includes regions that are comparatively simple, and others that are very complex; shown upon a single scale, either the complex parts are unintelligible, or the total is undesirably and needlessly large. Hence, just as the histologist aims first to obtain a general view of all the parts in their gross relations, and then focuses a higher power upon a selected region, so the delineator of encephalic structures should give first a view of the whole, if only an outline, and then an enlargement of complex parts to any extent required for their complete elucidation; he can hardly make this enlargement excessive. Compare, *e.g.*, Quain's figures, 258 and 290, and Figs. 669, 670, 671, and 695 in this volume.

§ 159. Terminal and limiting parts, membranes, and apparently atelic (functionless) parts and conditions should be distinctly shown, or the insufficiency of their representation admitted. "The little things of the brain" might well form the subject of an entire article. From the standpoints of physiology and medical practice such parts as the terma, valvula, crista, epiphysis, hypophysis, and habena, and such conditions as the reflection of the endyma upon the plexuses, and the dorsal limitation of the porta, are of comparatively slight importance. But their morphological significance is, at least in some cases, inversely to their functional activity, and they cannot be ignored without endangering the success of any attempt to understand or explain the structure of the brain.

§ 160. Anatomical figures should be something more than pictures conveying a general and vague idea. Where is there an adequate representation of the relation of the diatela to the habena, and of the cephalic end of the latter? From the published figures could any student be expected to comprehend the locations and boundaries of the "foramina of Monro" or of "Magendie"? The tenia is easily enough shown as a white band throughout most of its course, but where are its extremities accurately delineated? Any one can see the caudate prolongation of the striatum, but representations of its termination at the tip of the medicornu are as rare as are figures of the extremity of the filum terminale. Even so considerable a part as the flocculus is seldom figured in such a way as to display either its form or its attachment.

§ 161. The avoidance of the morphological incongruities and deficiencies which are to be detected in nearly every portrayal of encephalic anatomy demands the admission of three propositions, which are mere truisms in themselves, but radical affirmations when contrasted with their almost universal non-recognition in anatomical works:

1. Every part, organ, membrane,* or surface is either

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* My own use of slips of convenient size for notes and drawings and descriptions began in 1867 while I was assistant in comparative anatomy at the (Agassiz) Museum of Comparative Zoology at Cambridge, Mass. The slips were about three by five inches. When the first United States postal card was issued that size (13.5 × 7.6 cm., 5.25 × 3 in.) was adopted. But the subsequent introduction of other sizes has invalidated that standard, and the common and increasing employment of the catalogue card of the Library Bureau (7.5 × 12.5 cm. or 3 × 5 in.) may render it desirable to adopt that size for notes as well. Brief accounts of the "slip system of notes" are given in *Science*, January 16th, 1885, and in Wilder and Gage.

† Every student of any branch of natural history should compel himself to learn to draw, however slight may be his inherited artistic capacity. Not merely the laboratory students in Cornell University, but the members of the large general classes in physiology and zoology are required to make drawings of entire animals, and of the parts exposed in their dissections.

‡ The time has not yet come, and indeed shows no signs of approach, when I can look at even a familiar brain preparation without learning a new fact, gaining a better insight into what was already known, or receiving an impulse toward some special inquiry. A good example of the desirability of preserving specimens for later scrutiny is furnished in my last paper, 1900, *a* (see p. 196).

* So essential is the exemplification of celian circumscription and endymal continuity that the endyma should be represented by a distinct and rather heavy line, continuous excepting at the metapore; see p. 152, Fig. 687.

limited or continuous with some other part. If limited, its limits must be defined; if not, its extension must be indicated.

2. Every cavity is either open or closed. If closed, the continuity of its parietes must be demonstrated; if open, its communications must be shown.

3. Every elongated part has a middle and two extremities; not only the former, but the latter must be represented.

§ 162. Figures—original ones especially—should be multiplied and descriptions reduced. In descriptive anatomy, whether human or comparative, the text should be subordinate to the illustrations. Some treatises (Charles Bell, Meckel, Milne-Edwards, etc.) seem to have been prepared upon the idea that the description is essential and the figures merely supplementary; on the contrary, words should be employed only when pictures will not suffice—that is, for explanation, commentary, generalization, hypothesis, and manipulative directions.

The arguments for the multiplication of figures may be summarized as follows:

1. A figure is usually a guaranty that something like the object represented has been seen, at least by the artist, and that a certain amount of time has been devoted to its contemplation.

2. The information conveyed by a figure is more real, and likely to be more lasting, than that which is expressed in words. In respect to reality and impressiveness, the sources of knowledge may be ranked as follows, in an ascending scale: (1) Description; (2) picture; (3) model; (4) object seen; (5) object handled; (6) object personally prepared. The picture is thus intermediate in value between the thing itself and a description of it.

3. A figure, if clear and properly placed, is more readily understood than a description, and a saving of time is thus effected. It may be easier for the author to write than to draw, or even than to supervise a drawing, but his personal inconvenience or loss of time should not outweigh the gain to his readers. This applies particularly to dictionaries, cyclopedias, and journals, which are commonly read or consulted in haste. Editors and publishers would find eventual profit in offering to authors the fullest encouragement to employ illustrations so far as possible and curtail their descriptions in proportion. That it is rather the exception than the rule for such encouragement to be offered is probably due to several causes: (*a*) Publishing houses have usually a staff of printers who must be employed, whereas the various processes involved in the making of pictures are commonly done outside at extra expense; (*b*) authors too often content themselves with carelessly made copies of "stock figures" instead of insisting upon original representations of objects prepared by themselves. Hence, on the one hand, the exceptionally liberal publisher is liable to get a poor return for any allowance made for drawings, and, on the other, the exceptionally painstaking author is apt to be told that, at best, the engraving will be done if he will furnish the drawings; and, if he cannot draw himself, their cost is likely to deter him from their introduction. In short, all the existing conditions work to the disadvantage of the reader, who gets but a "pennyworth of [pictorial] bread to a monstrous deal of [verbal] sack."

Before this state of things can be amended the authors of books and papers must see clearly the importance of illustration; to paraphrase an epigram as to the making of an index, the drawings should be made or personally superintended by the author, even if some one else has to write the text.

4. Figures usually occupy less space than descriptions conveying an equal amount of information. This means condensation, convenience, and economy in the present, and a due consideration for our successors in the not far distant future. Exact data are not accessible, but no thoughtful and public-spirited person (unless he be a publisher or printer) can contemplate without concern the logical results of the present rate of book-making activity.

§ 163. Borrowed figures should be fully credited, and all modifications, whether of size or features, explicitly stated. To copy is to compliment, but unacknowledged copying is theft, and unspecified change is misrepresentation.

The ill effects of omitting to state the source of a figure are two: (1) The originator loses credit to which he is justly entitled; (2) the reader may be seriously misled by the apparent duplication of some really unique feature or the confirmation of an error. For example, in the representations of the meson of the cat's brain by Leuret (Leuret et Gratiolet, Pl. V., Fig. 2), the pseudocele ("fifth ventricle") is made even more extensive than in man, reaching almost to the splenium. The figure is reproduced, without credit or correction, in Mivart's "The Cat" (Fig. 129). Whoever remarks the coincidence in respect to the pseudocele, but fails to note that one figure is simply a copy of the other, may naturally infer that the feature in question is normal, or at least not anomalous.

On the other hand, if informed that three of Mivart's figures (125, 126, 129) were copied from Leuret, the student might conclude that the representation of the base of the brain (Fig. 128) was derived from the same source. This would be most injurious to the reputation of Leuret, for the figure in question displays several features (the size and direction of the hypophysis, the disconnected fissure on the temporal lobe, the relations of the pons to the trifacial and abducens nerves) which it is safe to say never were observed in a feline brain.

Nor is it enough to give the sources of figures in a list, or in the preface, as in Huxley's "Vertebrated Animals"; so great is the labor of preparing an original figure that the acknowledgment of it should be equally as explicit as that of a verbal quotation.

Finally, in the case of modified figures, it needs but a moment's reflection to see that nothing short of an accurate statement of the nature and extent of the alteration can insure full justice to the originator.

§ 164. Drawings should be made as notes. In many cases an outline* drawing, even if hastily made, would convey to the maker, or any one else, at a future time more prompt and complete information than could be embodied in writing covering the same space. But the general employment of sketches, in addition to words, or in place of them, can hardly be looked for until children are taught to draw the intelligible objects about them before they are drilled in the making of the—to them—unmeaning pot-hooks of the alphabet.

§ 165. Figures should be more frequently employed in preliminary or incomplete publication. Probably one of the reasons for the comparative infrequency of pictorial representations of normal, abnormal, and pathological structures, especially in journals, is the difficulty, often the impossibility, of preparing a detailed figure in time for publication. But this need not prevent the early appearance of a figure, if only in outline, illustrating one or more points of greatest importance.

§ 166. Figures should be based upon photographs. Photography enables the anatomist to (*a*) record the appearances of perishable specimens, or of such as are in course of dissection; (*b*) insure the proper perspective; (*c*) save time and labor upon the part of the draughtsman, and thus either reduce the cost of the drawings or render a larger number attainable.

It is seldom that a single anatomical preparation is so perfect as to display all that is needed, and yet present no superfluous parts; often, too, certain points are to be brought out with "diagrammatic clearness," others being subordinated or omitted altogether. Hence, as a rule, the photograph forms rather the basis for the completed figure, and two or more similar preparations may be required for the elucidation of all the desired features.†

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*There is a general and almost unconquerable predilection for shaded drawings. However advantageous shading may be in ordinary art as an element of finished pictures, and when merely a general effect is desired, in anatomical figures correct outlines are essential, and shading should be deferred until the last.

† A chief obstacle to the employment of photographs as a basis for figures of brains and embryos has been the difficulty of supporting such delicate objects within range of the camera in its usual horizon-

§ 167. Figures should be placed so as to be most readily understood and instructively compared. In comparing pictures of two or more houses, ships, or stoves, the architect, ship-builder, or dealer places them in such positions with regard to one another and his own eyes as may minimize the effort at mental transposition. If asked the principle on which he acts, he will probably say that no principle is needed, that he simply follows nature, experience, and common sense.

With few exceptions it seems to be reserved for those whose business is the contemplation of natural objects, who are credited with more than the average degree of intelligence, and who have at command the recorded experience of centuries, to disregard a matter whose simplicity is equalled only by its importance. In most works there is an utter absence of system. Seldom, indeed, are symmetrical figures placed otherwise than with the meson coinciding with that of the observer; but even this would be less likely to confuse than the apposition of transections of a subcylindrical mass like the myel with the dorsum above in one case and below in another.*

The prevalent carelessness in this regard may be ascribed to three sources: (*a*) The still too common idea that illustrations are of secondary importance; (*b*) the fact that most figures have been copied and thus placed without regularity, as in the original; (*c*) some time and trouble are required to reverse them.

§ 168. *General Rules for the Placing of Figures.*—These rules are based upon a consideration of the whole subject. There is probably no one of them to which exceptions may not exist; but such exceptions should always have a well-defined reason and not occur through inadvertence.

1. Figures should be coadjusted so as to facilitate comparison with one another and with typical structures in normal positions.

2. The dorsal side should be uppermost.

3. Direct views are to be preferred to oblique, though the latter are at times indispensable; *e.g.*, Figs. 720, 769, and 775.

4. Symmetrical figures, or parts thereof, should be so placed that the meson is vertical, *e.g.*, Figs. 664, 672, and 682.

5. When there is no choice between the right and left sides, the latter should be represented.

6. Of medisected organs, unless there is special reason for choice, the mesal aspect of the right half is to be shown.†

§ 169. *Designation of Parts upon Figures.*—The full technical names of parts should be given if possible. From the purely artistic point of view, of course, any extraneous line upon a picture is a disfigurement. But if it be once admitted that the primary object of an anatomical drawing is to convey accurate information, then, unless the shaded figure can be duplicated in an outline (as in Tiedemann, Vicq d'Azyr, and Dalton), there should be no sacrifice of the essential to the accessory.

It may be a question whether the names should be upon the parts (as in Gray), or at the sides of the figure and connected with the parts by lines (Gegenbaur). Upon the whole the latter method seems preferable, especially if the technical names are used.

§ 170. Abbreviations should represent technical terms; they should be uniform throughout the work, and be placed at the sides of the figure.

Four methods of designating parts by abbreviations have been employed: 1, By numbers and non-significant and ununiform letters, which may or may not be explained in the text (Owen); 2, by non-significant characters, uniform only in part, and explained at a distance from the figure (Reichert); 3, by uniform and significant, but partly vernacular, abbreviations (Parker); 4, by uniform technical abbreviations (W. and G.).

The advantages of uniformity in the use of abbreviations are obvious, but it is by no means easy to avoid the charge of ambiguity. Where uniformity is not attempted, care should at least be taken to avoid the use of the same abbreviation for the names of parts which are liable to be taken for one another. For example, in Schwalbe's two representations of the lateral aspect of the crura and adjacent parts (Figs. 280, 281), not only are opposite sides shown for no good reason, with some differences of detail which are puzzling rather than instructive; not only is the pons designated in one by *p* and in the other by *po*, and the tractus opticus by *to* in one and *tr.o* in the other; but the letters *tp* stand for the *tænia pontis* in Fig. 280, and in Fig. 281 for the *tractus peduncularis transversus* [cimbia]. Since these parts are similar in general appearance and direction, and only one appears in each figure, it is doubtful whether any but the most expert anatomist, thoroughly familiar with this somewhat obscure region, could escape at least a temporary misapprehension.

§ 171. Abbreviations should be explained in alphabetical order. The "practical" business man would exclaim, "Of course, how else should they be?" An "unscientific" child would adopt the alphabetical order with letters as he would the order of notation with numbers. But the super-scientific writer, especially if he be a German, scruples not to save a few moments of his own time at the expense of others, by giving the verbal equivalents of ten (Huxley, Fig. 19), fifteen (Balfour, ii., Fig. 271), twenty (Quain, Fig. 263), twenty-five (Schwalbe, Fig. 279), forty (Meynert [Stricker], Fig. 253), or even fifty-eight (Marchand, *Arch. f. mik. Anat.*, xxxvii., 331, 332) abbreviations, either in no recognizable order at all or as they occur upon the figure.* The time wasted by each consulter of the figure (not to mention the effect of just indignation) would nearly equal what it would have cost the author to place the abbreviations in alphabetical sequence. *Burt G. Wilder.*

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BRAIN: PACCHIONIAN BODIES.—These granulations, once falsely called glands, were perhaps first mentioned by Willis (1676), then by Méry (1701), and almost simultaneously described by A. Pacchioni. They start as minute spheroidal, partially vesicular outgrowths (villi of Luschka) from the arachnoidal layer of the pia—where it bridges fissures as well as where it rests on the gyres,—retaining its epithelial covering. They must not

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tal, or nearly horizontal, position. This obstacle is wholly removed by the photographic table devised by Professor Gage and used by us in Cornell University since 1873. With this the camera may be readily adjusted to any angle, and brought into a vertical position so as to cover an object lying upon cotton, or in alcohol, or even alive in water. The apparatus is described and figured in *Science*, April 11th, 1884.

* The common disregard of uniformity in this respect was made the subject of a communication by a medical professor to the Association of American Anatomists at its meeting in December, 1892.

† If the fuller discussion of this subject in the New York *Medical Journal*, August 2d, 1884, be consulted, the following corrections should be made:

Explanation of Fig. 57, last line, transpose *antimesal* and *symmesal*.
Fig. 59, for *antimesal* read *symmesal*.
Fig. 64, for *symmesal* read *antimesal*.

* Even more objectionable is the omission of the original pagination upon the reprints of papers. The printer does not always realize the conditions and the author often remembers when it is too late.

be confounded with granulations of the choroid or ependyma, with vegetations notably in the cavernous sinus (Hyrtl, 1862), nor with granular (aciniform) conditions of the meninges seen in inflammations. They are often clustered, become pedunculated, penetrate the opposed dura, and finally project into the overlying venous channels, and even excavate (in part repel) the bone. They are usually most abundant opposite the middle of the falcial sinus—more correctly opposite the largest parasinual spaces—but may occur on both sides, along nearly the whole length of this sinus, beside the transverse and tentorial sinuses, and even beneath the latter, also in the temporal fossa opposite the trunks of the medidural vessels and the frequently present temporal sinus. They occur not rarely 3 cm., and even farther, from the long sinus along the line of large incoming veins after the latter have left the pia, and also farther out at one point near the frontal border of the parietal bone, probably where a medidural artery bends to connect through the skull with temporal vessels. Hence, in general, they occur opposite intradural blood channels of some size, and especially those subject to continual variations in calibre (pulsation, ebb and flow). Their prevalent growth toward and into venous spaces has led to the assumption that the granulations themselves were venous structures, or opened into such (Key and Retzius, Kollmann, and others; it is not true that Trolard claimed this). But it is now generally thought that the injection of the spaces through the granulations must have been effected by the rupture of granulation vesicles.[*] From the intimate connection of the older granulations with the spaces, they become darker colored; or, on tearing the two structures apart, flecked with blood. But the younger free corpuscles are pale, whitish.

The parasinual spaces are said rather to diminish with age, while the granulations certainly increase. Up to the twentieth year they are rarely developed to any extent. In congenital defect of the heart, they appear early and excessive (case of Lambl, 1860; one of the writer). However, at all ages continuous or intermittent compression of the brain space, of whatever origin, is the most frequent cause of their over-development. Under this head fall intracranial tumors of any kind or seat. Repeated congestion, as in chronic alcoholism, is also an accepted factor, doubtless acting mechanically. Various systemic troubles, as nephritis and diabetes, favor the enlargement of these bodies, possibly by unusual variations in the encranial pressure.

In view of all the facts—viz., that while these corpuscles regularly occur opposite intradural (extra-arachnoidal) blood channels not necessarily venous, their growth is especially favored on the one hand by venous stasis, on the other by pressure from the side of the cranial space—it is evident that they result from the oft-repeated local oscillation of the arachnoid. As the cerebro-spinal fluid is subarachnoidal, it, especially when under pressure, forces that membrane at its weakest points into any depression, as that beside a dilated vessel —*the granulations always grow away from the cranial cavity, never toward it.* When, then, the favoring condition—be that even negative instead of positive—relaxes, the granulations, to the extent that they have formed, press against and penetrate superimposed structures, the continuous alternation of the conditions as continually favoring the process. This, as we believe, clear and simple explanation suffices for all the main features of these little growths.

Pathology, Clinical History, etc.—(*a*) Like the wrinkling of the skin, the turning gray and falling out of the hair, and many other processes, the granulations themselves should be considered pathological only when they become excessive or develop prematurely. (*b*) Calcification or ossification of these bodies is not unusual. They may contain deposits of so-called brain sand and even fat globules. (*c*) Where they penetrate into blood spaces and even a sinus, they so far interfere with the return current, and also favor thrombosis (only one case of the latter, Förster's, has been attributed to this cause). (*d*) Foveæ glandulares, sharp depressions or excavations in the inside of the skull (preceding *e* and *f*), quite analogous to that seen in aneurism of a dural artery, are sometimes found. From their more or less intimate relations with the sinus walls, Allen advises avoidance of the middle line in all operations upon the skull cap. However, the diploë itself is never opened by these growths as a new layer of bone always forms around the foveæ. (*e*) Small flat elevations of the external plate of the skull, opposite the foveæ, and hence near the superior median line, are mentioned by many. (*f*) Very rarely complete perforation of the cranium occurs.

1. Case of Weber-Ribes (1819; v. Pozzi); hole small, and covered by ligamentous membrane. 2. Luschka (p. 116); perforation of squamous portion of temporal bone. 3. Lecat (v. Heincke in Pitha-Billroth); pneumatocele capitis; skull at some points perforated by granulations of the dura. 4. Demme (1862; v. Mastin, "Venous Blood Tumors of the Cranium." Reprint, 1886). "On the left of the sagittal suture (posteriorly) was a sharp-edged opening the size of a cherry stone, through which protruded a Pacchionian granulation." 5. The writer's observation. Man of forty; had suffered over three years from a tumor of the brain; autopsy, August, 1887. At the favorite spot near the frontal border of the parietal, somewhat removed from the sagittal suture, there was a clean-cut, complete perforation of the skull by Pacchionian granulations. This was circular, fully 0.5 cm. across, surrounded even in the diploic portion by smooth continuous bone, and covered by periosteal membrane. At the border there was a very trifling over-projection of the outer bone plate.

It is recognized that such perforations—even when incomplete—may, from local injury, lead to the formation of epicranial blood cysts, inasmuch as the causative granulations usually traverse some blood channel.

(*g*) In a few cases growths of this class have pressed on passing nerves, causing local neuralgic or paretic symptoms. Though it has been claimed that at times these growths induce headache, it is probable that they are then but co-effects of some other cause. (*h*) In animals generally these corpuscles are not present (brains of sheep, calf, rabbit, dog, and cat examined). Luschka found them only in the horse. *William Browning.*

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BRAIN: SIMPLE MENINGITIS.—(Pachymeningitis, *παχύς*, thick; leptomeningitis, *λεπτός*, thin; simple, as distinguished from cerebro-spinal and tuberculous meningitis; meningitis of the convexity as distinguished from basilar meningitis.) Meningitis, in general, was first recognized as an affection separate from disease of the brain by Morgagni, 1760. Epidemic cerebro-spinal meningitis first attracted the attention of Vieusseux, of Geneva, 1805, and of Strong, North, Fish, Hale, Miner, and Williams, of our own country, 1806–1814, and was at that early period easily differentiated from affections limited to the membranes of the brain. Parent-Duchatelet and Martinet, 1821, first distinguished inflammation of the dura and pia mater, and Guérin and Guersant, 1827–1839, first distinctly recognized and set apart the tuberculous, granular, or basilar form of the disease. The first clear descriptions of the exclusively "simple" meningitis, from a pathological standpoint, are to be found in the works of Cruveilhier, 1830, and from a clinical standpoint, in those of Andral, 1834, and of Rilliet and Barthez, 1843. The recognition of the fact that simple meningitis is always a secondary affection is the result of the more accurate post-mortem observations of the last two decades, in the light of the recent investigations concerning infections, and the contributions from rhinology and otology.

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[*] This is a matter of interest in connection with the theory of brain pressure (*Hirndruck*). Bergmann lays much stress on the continuous (or intermittent) discharge of cerebro-spinal fluid through the granulations into the venous spaces; while Adamkiewicz ignores or argues against the existence of such discharge.

That the various forms of meningitis are caused by specific micro-organisms was pointed out by the workers in bacteriology, especially by Koch, 1882, who demonstrated the tubercle bacillus in tuberculous meningitis; by Leyden, 1883, who found a diplococcus in the cerebrospinal fluid and the pia, which Fraenkel and later Hauser showed to be identical with the pneumococcus; by Weichselbaum, 1887, who showed the presence of the diplococcus intracellularis meningitidis in epidemic cerebrospinal meningitis; and by Foà and by Bordoni-Uffreduzzi, who described a third and a fourth variety of the meningococcus.

Weichselbaum in Germany and Adenot in France, 1884, showed that meningitis occurring during or after an attack of pneumonia depended as a rule upon the same micro-organism that caused the pneumonia. Later observers have found meningitis frequently due to the pneumococcus in the absence of pneumonia. Thus the pneumococcus was found by Grasset in cases of meningitis occurring with inflammatory rheumatism; by Gabbi and Puritz in cases of meningitis associated with periarthritis and endocarditis; and by Ellehorst in a case of meningitis apparently due to fracture of the base of the skull.

The diplococcus intracellularis meningitidis is believed by some observers to be a variety of the pneumococcus, while others hold that it is quite a different organism. The latter view is held by Jaeger, who believes that the diplococcus intracellularis meningitidis is the cause of epidemic cases, while sporadic cases may be due to the pneumococcus. Jaeger proposes the name tetracoccus intracellularis for the micro-organism described by Weichselbaum as the diplococcus intracellularis, since this organism frequently appears in the form of tetrads.

In 25 cases of suppurative meningitis reported by Netter the pneumococcus was found in 18, the streptococcus pyogenes in 4, the diplococcus intracellularis in 2, and the typhoid bacillus in 1 case.

Next to the tubercle bacillus, the typhoid bacillus is most prone to cause purulent meningitis. Cases have been reported by Roux, Adenot, Kamen, Honl, Hintze, Fernet, Monsi and Carbone, Stühlen, Tietine, and other observers.

Next in the order of frequency, after the typhoid bacillus, is the bacillus coli communis, which has been found by Howard, Biggs, Sestre, Scherer, and others.

A rôle in etiology has been ascribed to the bacillus pyocyaneus by Kossel, Pesina, and Honl.

Among the pleomorphic bacteria that have been described in the exudates of meningitis are the cladothrix asteroides of Eppinger, and the actinomyces described by Moosbrugger, by Honl, and by Lenzine.

Pachymeningitis, inflammation of the dura mater, presents itself in two forms, external and internal, purulent and hemorrhagic, representing entirely different disease processes. Pachymeningitis externa, the hemorrhagic form, is really the result of a degeneration rather than of an inflammation; but in the absence of definite knowledge regarding the genesis of this disease, the two forms may be best studied together.

Pachymeningitis Externa.—Accidents or injuries which directly expose the dura, or effect its separation from the bones of the skull, with consequent extravasation of blood, whereby is implied, at least, a "hidden crevice" or some communication of the dura with the air, lead at once to inflammation of the outer lamella which may extend so as to involve all the rest of the membranes of the brain. Carious processes of the ear constitute an even more frequent cause of this condition. A mere microscopic breach in the thin wall of bone that forms the upper covering of the tympanic cavity will bring pus from the tympanum to the dura. So, also, caries of the ethmoid bone (ozæna) or other bones of the cranium (syphilis, carbuncle) may excite this form of meningitis; and even without caries, purulent inflammation of the mucosæ in the ethmoid and frontal sinuses may extend to the dura through the natural openings of communicating vessels. This complication has been noticed more especially in erysipelas after "mixed infection," whose nature it is to spread. As purulent pachymeningitis rarely remains confined to the dura, but extends, as a rule, to involve the pia mater, the symptoms, pathology, and treatment of this condition will be further discussed with leptomeningitis.

Pachymeningitis Interna (Consult Plate XV., Fig. 1).—The disease of the dura which merits most consideration, from its frequency, limitation, and recognizability in life, is that affection of the inner layer which is characterized by the extravasation of blood and subsequent development of an adventitious membrane, commonly known as hæmatoma duræ matris, and technically described as pachymeningitis interna hæmorrhagica. With these characteristics it is plain that internal pachymeningitis does not supply the requisite conditions, nor rise to the nosological dignity of an inflammation in the modern sense of the term. It develops oftenest independently of all infection, and should properly be discussed as a subvariety of cerebral hemorrhage.

The pathology of this affection remains as yet obscure. The early anatomists and clinicians were fain content with descriptions of the condition without venturing to express opinions concerning the nature of the disease. It was commonly held and taught that the disease consisted in the extravasation of blood, and the only question discussed regarded its situation. Thus Abercrombie and Andral, 1807, maintained that the blood was effused between the dura and the parietal layer of the arachnoid so called; while Houssard, 1817, located the extravasation in what was then, and for the sake of convenience is still, known as the cavity of the arachnoid. The hemorrhagic nature of the affection was nearly lost sight of when Bayle, 1843, considered the hæmatoma as an inflammatory product of the dura, but it was again restored by Durand-Fardel, 1854, who believed in the development and organization of a flat blood clot. Heschl, 1855, regarded the membrane as a highly vascular connective tissue, a view which Virchow, 1856, with his predilections for cellular pathology, elaborated into a hemorrhagic inflammation of the dura as the first process, and a subsequent infiltration of blood as the second. The authority of these pioneers carried their views with almost undisputed conviction up to our own times, when the studies concerning the nature and processes of inflammation and infection naturally diverted attention to the condition of the blood and blood-vessels as prime factors in the production of the disease.

That hemorrhagic pachymeningitis is not the expression of an ordinary inflammation is shown by the fact that no amount of irritation of the dura will produce it. Injections of ordinary irritants into and beneath the membranes of the brain of lower animals may be followed by purulent, but never by hemorrhagic, pachymeningitis. On the other hand, the injection of blood with all its constituents sufficed, in the experiments of Sperling, to produce the typical signs and lesions of the disease. The rôle of the fibrin in these cases is evidenced by the fact that a membrane was not developed after injections of defibrinated blood.

Internal pachymeningitis consists, then, in the extravasation of blood, the formation of a blood clot which, when the effusion is not too great or rapid, is flattened by pressure, to become subsequently organized into a membrane. In the first stage of the disease process, the thin layer of coagulated blood soon begins to show, in the separation of its fibrin, a meshwork which contains multitudinous blood corpuscles. At this time there is no apparent connection with the dura, whose epithelium remains intact. In the consolidation which continues, the clot assumes the appearance and density of a membrane, which now in reality develops, from the transformation of white blood corpuscles into spindle-shaped connective-tissue cells, whence the synonym, P. fibrinosa. The red corpuscles now gradually lose their coloring matter, which collects in spots on the surface, and in the texture of the membrane (P. pigmentosa) lose their regular contours, and finally become transformed into masses of protoplasm. Young vessels now connect the dura with the membrane, which becomes gradually more dense, thick, and adherent. In the mean time new layers of blood may be effused into the membrane already in process of formation, which consists thus of superimposed lamellæ—Virchow has seen as many as twenty,—for a time separable from one another. The effusion takes place chiefly upon the convexity of the brain, limited, in fifty-four of sixty-five cases collected by Kremiansky, quite precisely to the region covered by the parietal bones. It is rather more frequently bilateral than unilateral, being confined to one hemisphere in but forty-four per cent. of cases.

The source of the hemorrhage still remains a matter of dispute and doubt. Kremiansky thought it came from the middle meningeal artery, an origin which comports well with the situation of the clot; but Huguenin declares that he has never seen this vessel affected in any of his observations. This author is inclined to find the lesion in the veins which run from the cortex to the longitudinal sinus along the falx cerebri; and Pacchionian vessels have likewise been accused, but all alike without as yet satisfactory anatomical proof.

The chief danger of these effusions is pressure upon the brain, which shows itself in proportion to the amount of the extravasation. Huguenin has seen a hemisphere flattened by a large unilateral hæmatoma, which may be as large as a hen's egg—Eichhorst mentions effusions of 500 gm.,—and in some cases a lateral ventricle has been reduced by pressure to half its size. The great evil of pressure is obviated in many cases by the latitude allowed by atrophy of the brain substance, a condition rather, as a rule, coincident with hæmatoma of the dura. In fact, the greatest contingent of cases is found in connection with paralytic dementia, and cases independent of some degree of atrophy are comparatively rare.

When, from any cause, a real inflammation is engrafted upon this hemorrhagic degeneration, serum or pus may be found in connection with the blood which forms the hæmatoma. As curiosities in this direction, Virchow describes a hydrocephalus externus pachymeningiticus, and Weber saw, in a lamellated hæmatoma, blood in one cavity and yellow-green pus in another.

Various changes in the skull, membranes and brain have been observed in connection with pachymeningitis, but none so frequently as to belong to it of necessity. Thus the bones have been found thickened or thinned, with an agglutinated dura at times, the pia anæmic, hyperæmic and swollen, or cloudy and opaque, separable from or adherent to the dura, etc. The frequency with which general atheroma of the cerebral vessels is seen, with thromboses, softenings, apoplexies, scleroses, etc., of the brain, bespeaks the intimate relation of these processes to the development of the disease, in connection more especially with general paralysis, alcoholism, insanity, senile atrophy, etc.

Pachymeningitis is a much more frequent affection than is commonly believed. Savage records its presence in three per cent. of the autopsies made at the asylum at Bethlehem, and when it is remembered that there are more cases of dementia and insanity, not to mention alcoholism, out of than in asylums, it is seen that this percentage is far too low. It is safe to say that most of the cases remain undiagnosticated during life; and death, when it occurs, though perhaps caused by this affection, is ascribed to the disease in the course of which this accident develops. All authors agree in noting three-fourths of all the cases in the male sex, a proportion which corresponds to the relation of the sexes to the affections which produce the disease. For the same reason hemorrhagic pachymeningitis is a disease of advanced life. Exceptional cases at early periods of life—six months to eight years—have been recorded by Weber, Moses, Steffen, and others, mostly in connection with the venous stases from the strain of asthma, pertussis, etc., or the impoverished nutrition of blood-vessels from scurvy, leukæmia, and more especially pernicious anæmia; and cases have been more abundantly reported during adolescence and maturity in connection with tuberculosis, empyema, valvular lesions of the heart, the various forms of Bright's disease, the various infections (variola, scarlatina, acute articular rheumatism, and typhoid fever), and more especially local injuries of the dura (seventeen of seventy-four cases described by Schneider); but aside from these accidents, pachymeningitis remains a disease of age. The largest number of cases, twenty-two per cent., in the collection of Huguenin, occurred between the ages of seventy and eighty.

Symptomatology.—Internal pachymeningitis exists at times without a symptom to mark its presence. Moses reports such a case in a child, aged seven months, who died of catarrhal pneumonia. At the autopsy there was found a pachymeningitic cyst which covered the anterior half of the right hemisphere, though no sign of brain disease had ever been manifest in life. Slight extravasations often show no sign because of absence of pressure, or, if slowly effused, because of tolerance, which the brain acquires often in astonishing degree. In other cases the accident is overshadowed by symptoms pertaining to the original disease. These are, however, all exceptional cases. As a rule, the disease may be diagnosticated during life by signs which are not so valuable in themselves as in their etiological relations.

In the majority of cases the disease announces itself suddenly and violently. The patient is stricken with apoplexy. The hemorrhage may be so great as to cause death by compression of the brain within forty-eight hours. The nature of the disease, or more strictly, the localization of the hemorrhage, is, as a rule, in such cases impossible to determine. The first attack is not, however, usually fatal. In exceptional cases the patient may recover fully, but as a rule a train of symptoms ensues which more or less distinctly characterize the disease. These symptoms vary greatly in individual cases, vary according to the locality and extent of the effusion, as well as according to the nature of the original disease; but they do not differ in essential characters from the symptoms of meningitis from any cause. Headache, stupor, which may at any time deepen to coma, monoplegias, hemiplegias, or, in the irritant stage, unilateral twitchings and convulsions, limited at times to one extremity, or confined to the area of distribution of the facial nerve; aphasia, when the region of the language centre is compressed—these symptoms, together with an irregular or retarded pulse, vomiting, and more especially contracted or dilated pupils irresponsive to light, with little or no disturbance of general sensation, make up a group which as a rule distinguishes the disease.

But, as already intimated, it is not so much the symptomatology of the affection as its etiological relations which strictly define the disease. The general signs of meningitis refer especially to hæmatoma only when they occur in the course of general paralysis, chronic psychoses, alcoholism, chronic Bright's disease, pernicious anæmia, traumata, the affections mentioned in the discussion of the etiology of the disease.

Another distinguishing, but by no means so distinctive, feature to indicate the nature of the affection, is the recurrence of the symptoms. Total or partial recovery from all the general manifestations of meningitis is followed in pachymeningitis, as a rule, by repeated attacks, and though the special symptoms may show great variety in relapses or recurrent attacks, the general character of the new signs is definitely sustained.

The *Diagnosis* of pachymeningitis is based upon these two cardinal points: the existence of an underlying condition or causative disease, and the more or less rapid recurrence of the attacks. Cases are further characterized by suddenness of onset and rapidity of recovery. Dr. Whittaker had at one time under observation an individual affected with chronic alcoholism who was suddenly stricken with apoplexy on the streets. The patient was carried comatose to the hospital. The coma subsided in the course of a few hours, to leave a complete right-sided hemiplegia, which entirely disappeared in three days, leaving the individual in better physical and mental condition than for ten years. Many of the cases of so-called "serous" apoplexy, characterized by sudden onset, and more especially by speedy recovery, are really cases of pachymeningitis.

The predominance of symptoms indicating cortical lesion is another feature of diagnostic importance. Thus localized convulsions and contractions, monoplegias, contracted pupils, following an apoplectic attack in an individual predisposed to the disease by the factors already emphasized, point almost certainly to pachymeningitis.

Considerable diagnostic importance has been attached to rigidity of an extremity, which often develops as an expression of irritation of the motor centre of the extremity, to become later manifest by convulsion or paralysis.

Collins considers it rather characteristic that the cranial nerves always remain free.

A point of differentiation from other forms of intracranial hemorrhages is that the symptoms come on gradually and the stage of irritation is prolonged.

The age and sex of the patient must not be overlooked.

Basilar meningitis is differentiated by the youth of the patient, the family history, the presence of tuberculosis elsewhere, by its long prodromes, its insidious approach, its general and special hyperæsthesia, opisthotonos, boat-shaped abdomen, etc.

Cerebro-spinal meningitis prefers winter, soldiers, and children, occurs at times in endemic proportions, shows opisthotonos, herpes, and sometimes petechiæ, extreme hyperæsthesia, spinal lesions, and does not recur.

The *Prognosis* is always grave. Recovery without recurrence is possible, but not probable. The patient succumbs, as a rule, in a subsequent attack, if he does not fall a victim in the mean time to the original disease. The immediate prognosis is best established, as after any cerebral hemorrhage, by frequent observations of the temperature, whereby the degree of the rise after the initial depression incident to the shock would receive proper interpretation. A sudden or gradual elevation to a high grade (105° F.) at any time thereafter, independent of the original disease, is a sign of most ominous significance.

Therapy.—The treatment of pachymeningitis does not differ materially from that of any form of meningitis or cerebral hemorrhage. The application of an ice bag to the head, the local abstraction of blood by leeches or cups behind the ears or over the temples, "derivation" by purgatives (calomel, senna, croton oil), constitute the routine plan, which is sanctioned more by time and use than by benefit based upon demonstrable proof. Tranquillity of surroundings, with all the measures which make up a more or less perfect hygiene, is the most effective agent in prophylaxis in the chronic psychoses; while abstention from alcohol addresses the "causa indicationis" in cases dependent upon its abuse. Bright's disease, heart disease, pernicious anæmia, etc., in short, the underlying condition, calls for appropriate treatment, and paralyses, convulsive manifestations, persistent headaches, whatever symptoms may be left, are to be met with symptomatic treatment.

PACHYMENINGITIS CERVICALIS HYPERTROPHICA is a peculiar subvariety of meningitis, produced by great thickening of the meninges in the cervical cord, and marked by severe pains in the back of the neck and both arms, with atrophy of the muscles of the neck and flexors of the hands, and final spastic paraparesis.

LEPTOMENINGITIS.—It is possible, as already stated, that a real inflammation may limit itself to the dura mater alone, but such a distinct circumscription is very rare. Inflammation of the dura extends, as a rule, so as to involve the pia mater. The same qualification applies to the pia mater, though a strict limitation to the pia mater is more frequently observed. The subsequent remarks apply more especially to inflammation of the pia mater, with which the dura is, or may be, secondarily affected in greater or less degree. It is taken for granted that cerebro-spinal meningitis and tuberculous meningitis, diseases due to special causes, are not included under the title leptomeningitis, which embraces all other kinds of simple meningitis of known or unknown cause.

Leptomeningitis is always a secondary affection. The cases considered idiopathic become, under closer observation, so much fewer every year that it is more safe to appeal to unknown primary affections than to subscribe to the possibility of a spontaneous or idiopathic meningitis of any kind. A thorough conviction in this regard will alone lead to the searching investigation necessary in many cases to discover the original disease.

Affections of the nose, accessory sinuses, and ear constitute by far the most fruitful causes of leptomeningitis.

Chronic suppurative inflammations of the tympanic cavity, which constitute over twenty per cent. of all diseases of the ear, frequently lead to meningitis through caries of the osseous roof of the tympanum. The roof of the tympanum is composed of an excessively thin plate of bone, which is indeed at times congenitally defective, so that the way lies open to invasion of the cranial contents.

A more or less open avenue is also offered in the course of, or along the sheaths of, the facial and auditory nerves, and the vessels which penetrate the petrosal fissure. Communication by caries may be also directly established between the cavity of the cranium and the mastoid cells; while indirect involvement of the meninges may follow phlebitis and thrombosis of the cavernous, transverse, and superior petrosal sinuses, as revealed by dilatation of the veins and local œdema in the region of the mastoid process. Tuberculosis plays a prominent rôle as a special cause in the production of all these processes, while syphilis furnishes a small contingent of cases through caries of the upper meatus of the nose.

Every meningitis whose cause is not obvious should excite suspicion of disease of the nose, accessory sinuses, or of the ear. So, also, diseases of the nose, especially those involving the accessory sinuses; and every case of otorrhea, which may sometimes reveal itself to the sense of smell in an offensive odor, before or in the absence of visible discharge, should excite the fear of possible meningitis.

Trauma or injury to the cranial bones constitutes a not infrequent cause of simple meningitis. When compound fracture has occurred, or direct penetration has been effected, the sequence is sufficiently simple. In other cases the meninges, though not directly exposed, become affected through phlebitis, thrombosis, or suppurations occurring in the patulous veins of the diploë, whereby is implied, as previously intimated, some hidden crevice or pre-existent communication with the air. A far more infrequent involvement of the meninges occurs at times when an abscess in the interior of the brain reaches its periphery, or bursts into a lateral ventricle to come in contact with inflections of the pia mater at the base of the brain. So-called brain "softenings," which consist simply of brain and tissue débris, and simple hyperæmias, the so-called "congestions" of the brain, including sunstroke, could not, with our present knowledge of the nature of infections, produce a leptomeningitis.

Next in frequency to the direct invasion of the meninges from disease of the nose, accessory sinuses, and ear are the metastatic processes from distant depôts of infection. Any one of the acute infectious diseases may be thus attended or followed by meningitis, which is justly regarded as the most serious complication which can occur—which, indeed, imparts a sudden gravity to an otherwise mild case of disease. Of all the acute infections, pneumonia is the disease in which this complication most frequently occurs. The intimate relations of tuberculosis of the lung and brain in the frequent sequence of basilar meningitis upon tuberculosis pulmonum, prepare us in a measure for the frequent supervention of meningitis in the course of croupous pneumonia. The same connection or relation has been observed also in cerebro-spinal meningitis, and bacteriologists have pointed out the striking resemblance of the micro-organisms found in these two affections. Pyæmia and septicæmia may be said to vie with pneumonia in the production of metastatic meningitis, while endocarditis, empyema, acute articular rheumatism, the exanthematous diseases—more especially variola and scarlet fever (aside from ear disease), and very rarely typhoid fever—diseases mentioned in the order of frequency, furnish exceptional cases. Hinsdale reports a fatal case of purulent meningitis in a new-born child, due to a bacillus belonging to the colon group, which had apparently gained entrance to the body through the umbilicus. As curiosities equally illustrative, however, of the nature of the process may be mentioned the cases of meningitis which have followed such trivial infections as vaccinia and mumps.

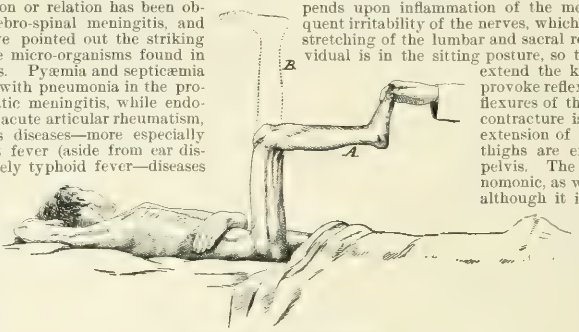

Fig. 993.—The Kernig Sign.

In a few reported cases, a paradoxical pupil reaction has been noted, the pupils being contracted to the size of a pinhead in the dark, and widely dilated in the light. The condition is rare and no satisfactory explanation of it has been given.

The morbid anatomy and symptomatology of leptomeningitis do not differ—aside from the fact that the convexity is more often involved than the base, when the inflammation is due to metastatic and traumatic causes—from the morbid anatomy and symptomatology of cerebro-spinal meningitis (to be described farther on, in this volume).

The *Diagnosis* of meningitis in connection with disease of the nose, of the accessory sinuses, or of the ear, or with a trauma of the bones of the cranium, is very easy, as a rule, but the diagnosis of metastatic meningitis is oftentimes exceedingly difficult. High fever and blood-poisoning may be productive of symptoms which so closely simulate the signs of meningitis as to render an absolute diagnosis impossible, at least for a time. The persistence of these signs after subsidence of hyperpyrexia sometimes declares the disease. Tuberculosis, pyæmia, scarlatina, variola, erysipelas, and typhoid fever are the affections which oftenest create doubts as to the diagnosis. But if close scrutiny be made of the etiological factors, and close attention be paid to the course of the disease, the diagnosis, as a general rule, soon becomes clear. In distinction from tuberculosis and typhoid fever, it may be said that meningitis develops quickly, almost suddenly, with violent pain in the head, active delirium, and often with stiffness of the muscles of the neck, or retraction of the head.

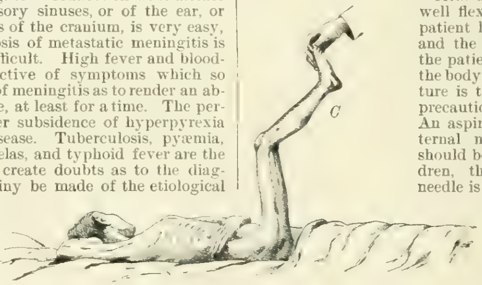

Fig. 994.—The Kernig Sign

The Kernig Sign.—In meningitis, according to Kernig, of St. Petersburg, if the hip be flexed so that the thigh is at a right angle to the body, the knee may not, without undue force, be extended in some cases beyond 90° (Fig. 993, *A*), never to the point of full extension (Fig. 993, *B*), and not farther than about 135° or 140° in any case (Fig. 994, *C*). With the hip extended, the knee may be readily straightened (Fig. 994, *D*). Thus, the ability readily to extend the knee, when the hip is flexed at a right angle (Fig. 993, *B*), would speak strongly against the presence of meningitis.

Netter believes that the sign described by Kernig depends upon inflammation of the meninges and consequent irritability of the nerves, which is increased by the stretching of the lumbar and sacral roots when the individual is in the sitting posture, so that the attempt to extend the knee is sufficient to provoke reflex contracture of the flexures of the leg. Such reflex contracture is not produced by extension of the knee when the thighs are extended upon the pelvis. The sign is not pathognomonic, as was at first claimed, although it is of great value in diagnosis. Netter has observed it in forty-five out of fifty cases of meningitis. Cipollina was unable to find it in some severe cases of meningitis, and did find it in other affections without the symptoms or lesions of meningitis. Packard has reported three cases of meningitis in infants, with the diagnosis confirmed by autopsy, in which the Kernig sign had been persistently absent. The absence of the sign was ascribed by Packard to a diminution of normal muscular hypertonia in infants. In another case the sign was present but no anatomical cause for death was found.

Lumbar Puncture (Quincke).—Puncture of the vertebral canal, which was originally used as a therapeutic measure, has proven of great value in diagnosis. At first the method was used in the study of diseases of the vertebral canal; but with the knowledge of the communication between the subarachnoid spaces of the brain and those of the spinal cord, the method has come into much more general use in the diagnosis of diseases of the interior of the skull.

Method.—The trunk should be well flexed, preferably with the patient lying upon the right side and the legs drawn up, or with the patient sitting up and bending the body well forward. The puncture is then made, under aseptic precautions, with a clean needle. An aspirating needle with an internal measurement of 1 mm. should be used in adults, in children, the ordinary hypodermic needle is sufficiently large. With the object of reaching the subarachnoid space at the beginning of the cauda equina, the needle is introduced between the second and third or third and fourth lumbar vertebræ. The puncture is made in the median line in children; in adults it is better to make the puncture close to the spinous process a little to one side of the middle line, in order to avoid the strong supraspinous ligament. The needle is introduced inward and slightly upward, to a maximum depth of from 2 cm. for children to 6 cm. for adults. When the needle enters the subarachnoid space, a varying amount of cerebro-spinal fluid will usually flow out, either in drops or in a stream. Occasionally the fluid will not escape or the flow will suddenly cease, probably through the occlusion of the needle by a flake of fibrin or in consequence of an obstructing filament of the cauda equina. To avoid injury to the spinal cord, it is better to detach the aspirator from the needle, and thus withdraw the fluid without force. Any fluid that is withdrawn should be examined macroscopically, microscopically, and bacteriologically. Thus may be determined, first, whether the fluid be clear, turbid, purulent, or bloody; and second, the micro-organisms that may be present either as the primary cause of the meningitis or as a secondary infection.

Osler confirmed the diagnosis in this way in thirteen out of seventeen cases. (See also p. 248 of the present volume.)

Tuberculosis and typhoid fever show typical temperature curves, with lung symptoms in tuberculosis, and abdominal symptoms in typhoid fever. In scarlatina, variola, and erysipelas it is rather a question of detecting a complication, as each disease shows characteristic eruptions upon the surface. Here, too, the persistence of cerebral signs after subsidence of the high temperature is of value. Septic and pyæmic diseases follow wounds, are attended with chills, and show joint affections and internal metastases. Ulcerative endocarditis, a septic process, has the same history. Uræmia is recognized by the dropsy, the condition of the urine, and, so far as the nervous symptoms are concerned, by the predominance of convulsions.

Cerebro-spinal meningitis is differentiated by the more prominent disturbances of sensation, by herpes, and by the occurrence of other cases. Basilar meningitis occurs more especially in children affected with tuberculosis elsewhere, or who come of tuberculous stock. It has long prodromes, and a longer duration. Its symptoms are less acute and intense. It more frequently implicates the membranes of the spinal cord. Pachymeningitis is a disease of age. It occurs in drunkards, and in cases of dementia paralytica, chronic insanity, etc. It shows a more fluctuating course. It must be repeated again and again that the various forms of meningitis are to be separated and recognized more by the etiological relations of the disease than by any difference in symptomatology.

The *Prognosis* is far more grave than that of cerebrospinal, but not so absolutely fatal as that of basilar meningitis. The great majority of cases terminate fatally, in coma or convulsions, in the course of from two to ten days.

The *Treatment* of leptomeningitis does not differ in any way from that of any other form of meningitis; what little may be accomplished for the relief of symptoms will be mentioned under *Cerebro-Spinal Meningitis, Epidemic.*

The physician who is thoroughly indoctrinated as to the dangers of disease of the nose, of the accessory sinuses, and of the ear, and who is thoroughly familiar with the researches regarding the nature of infection, will prevent many cases of meningitis by timely treatment of the nose and ear, and by maintaining scrupulous asepsis in the management of all wounds of the skull.

James T. Whittaker.
George E. Malsbary.

BRAIN, SOFTENING OF.—The brain is said to be softened when its consistency is less than that taken as a normal standard. Diminution of consistence, however, shows but a part of the morbid work of an affection in which this phenomenon is only a circumstance quite accessory to the more important cerebromalacia, and the term in its literal acceptation could apply only to a diminution of the cohesion of the brain tissues, while their other properties remained intact. Softening, being a symptomatic word with a pathological meaning, like the word apoplexy, is rather a survival of a former belief, and its use is perhaps for this reason undesirable; but the name having been retained amid the fluctuations of opinions of writers on the subject, and in spite of its incongruity and the fact that it is often applied to cases in which there is really no softening, it is now employed to designate a necrobiotic process that occurs in the elements of the brain tissues and that is consequent upon nutritive changes ordinarily attended by sensory, motor, and mental disturbances, which may vary according as the lesion is circumscribed or general in character.

Pathological Anatomy—Descriptions of the pathological changes accompanying occlusion of the cerebral arteries and the so-called encephalomalacia are comparatively new. Their discussion is limited to contemporary authors, who have definitely settled certain points involved in the development of a new subject, notwithstanding diversity of opinion touching the nature and character of softening.

In determining the question whether the diminished consistence or diffluence of cerebral substance be of pathological origin, two sources of deception should be guarded against; for this condition may be the result either of cadaveric decomposition or of accident happening during the extraction of the brain from the skull. The genuine morbid appearances are then to be distinguished from the artefacta produced by the investigator, and from the spontaneous changes occurring after death. Nor should the condition be confounded with diminished density or specific gravity. Normal white matter gives a specific gravity of 1.040, but when softened it is from six to eight degrees of the hydrometer scale lower than the normal condition; and the consistency of the brain is the same in individuals of all ages excepting the newborn and very young children. Season, temperature, and the disease to which the patient has succumbed affect this consistence. An epileptic, dying during a paroxysm, in the month of June, by asphyxia from the penetration of food into the respiratory ways, has been known to present at the necropsy, twenty-four hours afterward, a completely diffluent encephalon. In a second instance, forty hours after death, with the same temperature, and in marasmus and an organic affection of the liver without cerebral symptoms, the brain was found to be in such a softened state that when it was placed on the hand the fingers penetrated by reason of its weight alone; while that of another cadaver, examined seventy hours after death and twenty-four hours after the necropsy, was far from this state of softening.

Though most frequent in old age, softening spares no period of life, its occurrence having been noted in the new-born and even in the fœtus. That form peculiar to the senile condition appears to have served as a type in all the descriptions given by the best writers, who seem to have overlooked the pathological conformity shown in the failure of the nutrition as the primary and common cause of cerebral softening at the two extremes of life. In the new-born the profound disturbance of nutrition which, through the intermediary of the blood, disintegrates an organ whose softness has not yet been effaced by age, is essentially the same as that which in the senile state prepares for arterial and cardiac lesions, the formation of embolism or thrombosis, and the consequent incomplete irrigation of the cerebral substance by the blood. This starvation of the brain consequent upon diminished supply of arterial blood is now spoken of as necrobiotic and non-inflammatory in its nature. Such terms, however, as cerebral infarction and necrobiosis, though establishing facts, do not explain the phenomena of cerebral disintegration.

Certain observers recognize in brain softening inflammation of an absolute kind; some regard it as a morbid state analogous to senile gangrene; others see a vital lesion affecting the nutritive integrity of the brain; while still others consider it as a lesion of nutrition owing to local ischæmia, provoked by arrest or diminution of circulation either in one of the cerebral arteries or in the capillaries of the brain.

This profound trouble of nutrition, the essence of which is unknown, may occur as a primitive necrobiosis of the brain substance, or this necrobiosis may be preceded by a vascular lesion that causes a want of supply of blood effected through embolism, the local formation of a thrombus, or by compression of the vessels. If a cerebral vessel be stopped, that part of the brain supplied by the vessel is suddenly deprived of nourishment, and this will be definitely the case if the embolism remains in place. When the vessel in question is a terminal artery, which does not exchange blood with other arteries, there will be immediate stoppage of cerebral function, followed by rapid changes of the brain elements, into fat and eventually into the liquescent state.

The anatomical characters and circumstances that preside at the evolution of cerebral softening have been fairly made out. Observations in this direction warrant the statement that the *arteria fossæ Sylvii sinistræ* is most exposed to embolic occlusion, which circumstance may be explained anatomically by the difference in the angles at which the left carotid and the innominate arteries are given off by the aorta. For this reason the left carotid is liable to catch an embolus coming from the heart, and the left Sylvian artery being the terminal artery in question, the regions provided by this vessel are consequently most in danger of being affected by the embolic process. These regions are the nucleus lenticularis, the terminal nuclei in part, the external capsule, and part of the internal capsule. The terminal branches of this vessel supply the second and third frontal convolutions, the island of Reil, and proximal surroundings, these being the portions of the brain most likely to suffer from the necrobiotic process. Further anatomical changes in the cerebral substance may result from the formation of an autochthonous coagulation, in consequence of degeneration of the intracranial vessels. Circumstances favoring the rapid formation of the thrombus are diminished motor force of the heart, roughening of the inner walls, narrowing and loss of force and elasticity of the vessels. Tumors of rapid growth, and inflammatory processes and their surroundings, which compress the vessels to such an extent as to lead to softening, are phenomena often observed in connection with softening. Occasionally the affected vessel is discovered entirely empty at the post-mortem examination, and for this reason it is supposed that the occluding mass has been reabsorbed.

The first fact of importance in connection with the pathological details of softening is the infrequency of anatomical changes in the cerebral substance when the seat of obstruction is on the cardiac side of the circle of Willis, which permits the prompt re-establishment of the circulation on account of its free anastomosis. If, however, the embolus is lodged in one of the terminal arteries of the basal arterial system, and a large region be thereby deprived of the necessary supply of fresh blood, there will be flowing back from the veins, and the tissues will become hyperæmic and œdematous, and filled with small extravasations known as hemorrhagic infarctions. In this simple necrobiotic change, the blood and coloring matter pass through the ordinary metamorphosis, the tissue of the brain swells and decays, leading to the rapid development of masses of granular cells, and finally to fatty emulsion. Later, the diseased focus may become reabsorbed and a cyst remain in the place of the softening, but this is rare; in fact, such a result may never occur except in the case of a small focus of inflammation. The process is more often followed by red sanguineous infiltration and yellow softening. The color, depending merely upon the amount of blood in the tissues, is, however, not an essential point, nor is sanguineous infiltration always present, and yellow softening is sometimes observed without its presence.

Etiology.—Although the etiology of the large group of clinical symptoms popularly known as brain softening touches one of the most delicate points of medicine, but little satisfactory is to be said regarding its remote causes. Among those which predispose more or less are old age (from fifty to eighty) or agedness, chronic alcoholism, syphilis, sexual excesses and fast life, Bright's disease, acute rheumatism, the dartrous diathesis, chorea, scarlet fever, insolation, intense cold, intense and long-continued intellectual exertion, severe and protracted emotional disturbance, misery, fright, overwork and responsibility, the abuse of opium, menstrual troubles, and, according to some authorities, the puerperal state. The cachexias and the inopectic diathesis (that is, a tendency to embolism, to thrombosis, and to coagulation of fibrin) are adjuvant causes, the importance of which should not be overlooked. Among negroes, the intertropical races, and the inferior races generally, softening and other forms of brain disease are infrequent, but the aptitude for such disease grows with the degree of perfection of the species. Women are less subject than men, principally for the reason that, being women, they do not undergo the strain and exhaustion of high brain energy and severe muscular labor, and are not so exposed as men to the poison and excitement of alcohol, syphilis, and tobacco.

Brain softening is the pathological sequence of many different conditions; but the more important causes that bring about the results in question may be stated as follows, when brought concisely together: endocarditis, through the production of movable products; myocarditis, through the formation of thrombosis in the heart; all processes in the lungs leading to coagulation or to the reception of septic material into the veins of the lungs; aneurism of the aortic arch; atheroma of the cerebral arteries; tumors of the brain, and even encephalitic foci; syphilis of the brain; the accumulation of pigment and pigmentous flakes in the blood, in connection with severe cases of malarial intermittent fever; and capillary occlusion through drops of fat. Other sources are injuries and inflammations of the bone, the occlusion brought about by pus cells or white corpuscles, and the blocking of the vessels by lime metastasis.

Of the phenomena of the occlusion of the intracranial vessels usually preceding the encephalomalacia, it is impossible to present a clinical picture in definite terms without going into the details of embolism, thrombosis, and hemorrhage, for full particulars of which the reader is referred to their respective headings. Although spoken of in the same connection, cerebral softening and occlusion of the cerebral vessels are not necessarily interdependent, since softening does not always follow occlusion, and for this reason there is a tendency among some to consider softening as a distinct pathological condition.

Symptoms.—Softening of embolic origin always begins by the symptoms peculiar to encephalic effusion of blood, or to those of apoplexy, the word being taken in its traditional sense. In fact, the symptoms are so similar to each other that their differentiation may be a matter of great difficulty to the most experienced. The symptoms that characterize the early period of *Embolism* are sudden. Without premonition the patient is seized with a sudden dizziness, or a momentary headache, and with an involuntary cry falls consciousless; motion and sensation appear to be extinguished, and unilateral paralysis, generally of the right side, follows. The only apparent difference between the symptoms occasioned by embolism of a cerebral artery and those of hemorrhage is the more transient state of the unconsciousness. For this reason part of the symptoms are often spoken of as apoplectic. In some cases, when the symptoms are less distinct, the unilateral paralysis forms a prominent feature. Other cases are prominently marked by more or less dizziness, by the absence of coma, by convulsions, and by unilateral symptoms. This seems chiefly the case when embolism occurs in a circumscribed smaller cortical region, or when the embolus is reabsorbed and the circulation restored. Vomiting sometimes attends the onset of the attack; at other times delirium of a transitory character occurs; and in many cases sudden aphasia results from the anæmia produced in the speech centre by the embolic occlusion of the artery supplying that region. There seems to be diversity of opinion among observers regarding the state of the pupils during the onset of the attack; it is probable, however, that they vary in different cases. At the fundus of the eye there may be found papillary or retinal œdema. It is only in chronic senile cases that papillary atrophy occurs.

Thrombosis of the cerebral vessels is usually attended by premonitory symptoms, as persistent headache, either diffused or localized, slight dizziness, a sense of general confusion, unilateral disturbances of sensation, and even violent transient paresis. Further development of the trouble gives rise to excitement and active delirium, causing the patient to get out of bed at night and to commmit other unreasonable acts. Symptoms of depression may follow this period of excitement, the patient becoming apathetic and answering questions with difficulty. His movements are slow; there is tendency to somnolency; and a notable decrease occurs in the psychic functions, this decrease being characterized mainly by failures of the reasoning process, and by a more or less compromised memory, both of which are shown in verbal amnesia and other dysphasic affections. The humor is changing and emotional, and later the mental and other symptoms may become those of localized cerebral disease generally. As the patient goes into greater decline there may be bed-sores, and he may die from these; from an intercurrent malady, as a cardiac, renal, or splenic complication, or a pulmonary phlegmasia; or a new attack or some new lesion of the encephalon may carry him off. Generally the patient dies in a state of profound adynamia. The size and physiological importance of the occluded vessels determine the difference in the extent and duration of the symptoms. In fresh and vigorous subjects the occlusion of a small vessel may be followed by recovery, if the collateral circulation be established before the stage of necrobiosis begins. However, in most cases of autochthonous thrombosis that survive, the subsequent history is that of chronic localized brain disease, and of the motor, sensory, and intellectual disturbances that follow. The same may be said of embolic softening. Actual softening being fully established, the most prominent symptoms are permanent weakness, often persistent hemiplegia accompanied by athetoid spasms, and progressive mental weakness ending in paretic dementia. With the exception of the disturbances of vision, the affections of the special senses are the same as those that occur in connection with cerebral hemorrhage. The same is true of the sensory, trophic, and vaso-motor disturbances. Sudden amaurosis from occlusion of the arteria centralis retinæ has been observed to occur in some cases of embolism. Anæmia of the fundus has also been found; and certain observers attach much diagnostic importance to the arterial and venous hyperæmia of the retinal vessels and to congestion of the optic disc.

The paralyzed limbs are generally those of the right side, for the simple reason that the left Sylvian artery is oftener occluded than the right. Bilateral paralysis may, however, follow bilateral vascular occlusion. Since we are unable to offer any satisfactory explanation of either the presence or the absence of contractures of the paralyzed limbs, they can scarcely be regarded as of pathognomonic significance. Motor restlessness, though characteristic of the worst cases, is greatly influenced by heredity. A patient of bad nervous antecedents, with a spot of progressive softening in one of the corpora striata, may become noisy and restless and suffer from insomnia, while another, with no nervous heredity and under the same conditions, is quiet and manageable. As enfeeblement progresses, the motor symptoms are particularly noticeable in the paretic walk and aphasic speech, the latter resulting from a disturbance of the secondary coordination consequent upon a lesion of the basal motor ganglia. (See *Aphasia.*)

A brain affected by softening being on the verge of dissolution, the most prominent and troublesome symptom is the disturbance of the mental functions. The faculty most prone to fail is memory. The vesicular neurin not being susceptible to the impression of events, the patient is unable to recall recent experiences and impressions with distinctness. The destructive metamorphosis of the convolutional structure is further shown in the impairment of the reflective faculty or power of judgment; and as the cerebromalacia progresses the patient may become whimsical and peevish, or his affective power may be deadened, and the intellectual faculties may decline into childishness or gatism and finally become extinct.

The occurrence of these mental changes in connection with the situation of the brain lesion may be further studied under other headings (see *Brain Diseases: Diagnosis of Local Lesions*, and *Brain: Functions of the Cerebral Cortex*).

Diagnosis.—The diagnosis of cerebral softening should be based upon the history of the case and the proving of such fundamental conditions as may produce hemorrhage and embolism or thrombosis. Hemorrhage cannot be distinguished from thrombosis by any absolute means, notwithstanding the various diagnostic signs that have been proposed at various times; but the condition of softening may be established with a probability bordering on certainty when the associated symptoms are taken into account. When the premonitory symptoms have continued for a long time, the so-called apoplectic accidents point to cerebral hemorrhage rather than to embolism, but the symptoms in all probability may be owing to thrombosis. Gradual march of the paralysis indicates thrombosis rather than cerebral hemorrhage. The rapid appearance or disappearance of the attack, and the situation of a centre of softening in the left hemisphere, point rather to embolism than to thrombosis. It can also be affirmed with almost entire certainty that the encephalic foyer is of embolic origin when the presence of the symptoms permits us to suspect the formation of splenic or of renal infarction. Such symptoms would be likely to occur after a sudden attack in a young subject with an active *bruit de souffle* and enlargement of the spleen, pains in the lumbar region, and the presence of blood in the urine. Cerebral softening may be confounded with hemorrhage, encephalitis, hæmatoma of the dura, and with tumors. In tumors the speech and intellect are generally unaffected, and there is pain with convulsions, vomiting, double optic neuritis, and choked disc; in hæmatoma the history of the case is the main reliance in making out a correct diagnosis; while in encephalitis there is a considerable rise in temperature and the evidence of tissue action in the respective region of the brain, which is notably absent in softening. The lowering of temperature, almost constant at the outset of cerebral hemorrhage, is absent in softening; aphasia is more frequent; paralysis of a mobile character increases by abrupt stages, and death may occur during the initial coma. The signs of arterial atheroma are of no value.

Prognosis.—Softening of the brain, more or less grave according to the extent and intensity of the functional troubles, is a disease that ends in death after a certain time, varying from a few days to several months or years. More die of the acute than of the chronic form. Some think the malady curable, but it leaves ineffaceable marks in the most favorable cases, and the reported recoveries are to be looked upon with a great deal of doubt. They are said to have occurred in young and vigorous subjects; and when it is taken into consideration that the symptoms may have been incorrectly observed, or that they may have been those following various depraved states of the nervous system, the statement becomes more problematical. When not carried off by the initial symptoms, the patient is left with an incurable infirmity, in one of the most unfavorable conditions known. With the gradual enfeeblement of the intellect he is constantly threatened with new symptoms, and the reproduction of the original causes that produced the centre of softening. In fact, these causes greatly influence any forecast that it is possible to make concerning the march and duration of the malady. As a rule, it may be said that the indications are the more favorable in simple circumscribed embolism, and most unfavorable in cases of autochthonous thrombosis. The prognosis is worse when there is slight impairment of the intellect, sensibility, and motility taken together than it is when any one of these singly is profoundly impaired. A case may be regarded as hopeless as long as the underlying cause of the attack remains, and extreme gravity is to be attached to such symptoms as rise of temperature and bed-sores.

TREATMENT.—The causes that produce softening are difficult to remove and the therapeutical treatment of their effects is generally barren in results, notwithstanding correctness of diagnosis and the most judicious efforts to meet symptoms as they occur. Once established, senile softening is not amenable to treatment. Preventive measures being out of the question, except when the premonitory symptoms have continued for a long time, a consideration of the causes becomes fundamental matter, and the state of the heart and its action the main question. A declivous position of the head and perfect rest in a uniform temperature are advisable during an acute attack, while the body should be kept warm by artificial heat, warm clothing, and the cautious administration of stimulants. The caution in regard to stimulation is the more to be observed if there be the least suspicion of hemorrhage. In such a contingency it is deemed wise to act as if the case were one of cerebral hemorrhage, since hemorrhage is more likely to occur than occlusion, and the harm following stimulation in such a case seems to justify the diagnostic doubt. Symptoms pointing to a severe collateral hyperæmia may be treated with large doses of the bromides, sinapisms, dry-cupping, and mild purgation. The actual cautery and bleeding are to be avoided; but when there is general vascular irritation, leeches may be applied to the anus and behind the ears, in connection with intestinal revulsives and cold applications to the head. Digitalis, or strophanthus with glonoin, and amyl nitrite, are indicated, if the arterial tension be weak. Their use is, however, inadvisable in old persons. Recourse may be had to nervine tonics and to mild forms of slow derivation after the attack has passed. The diet should be strictly regulated, all intellectual effort should be interdicted, the integrity of the nutritive functions should be maintained as much as possible, and the methods of treatment applicable to the chronic symptoms of circumscribed cerebral disease should be generally observed.

Irving C. Rosse.

BRAIN, SURGERY OF THE.

HISTORY.—Although in 1871 Broca located a cerebral abscess in the speech centre, and greatly relieved the patient by trephining, modern brain surgery begins properly with a modest report of a case by Macewen in the Glasgow *Medical Journal* for 1879, xii., 210, and a later more elaborate paper, by the same author, in *The Lancet* for 1881, ii., p. 541. In these papers he narrates three cases, occurring in 1876 and 1879, in which cerebral disease was located by focal symptoms. The first was a case of convulsions of the face, arm, and leg, in the order named, following a fall on the right side of the head. A trephine opening of the dura evacuated two ounces of blood, and the boy recovered without any febrile movement.

In the second case the symptoms pointed to a lesion of the frontal lobe, and, after trephining, a tumor of the dura mater was dissected out. The patient died eight years subsequently from Bright's disease.

The third was a case of cerebral abscess, existing not at the site of a prior injury marked by a distinct cicatrix, but correctly diagnosticated in a totally distinct position, that is, in Broca's convolution, by the focal symptoms. The parents declined an operation, and the child died. After death an operation was done precisely as it would have been done during life, and an abscess was found, the size of a pigeon's egg, at the spot indicated by the localizing symptoms.

In spite, however, of this remarkable paper, the surgical world seemed blind to its opportunity. But in *The Lancet* for December 20, 1884, Dr. Hughes Bennett and Mr. Godlee narrated a case of subcortical tumor of the brain, diagnosticated by the localizing symptoms alone and before operation. When the dura was opened no tumor was visible: but so certain were they that a tumor existed that an incision was made in the apparently healthy brain tissue, and a morbid growth the size of a walnut was found one-fourth of an inch below the surface. This case, though ultimately unsuccessful because of suppurative meningitis, instantly arrested the attention of the surgical world by the precision of the diagnosis, the success of the operative technique, and the evidence it afforded that we could successfully cope with heretofore hopeless cases. Its very failure, like the failure of the first Atlantic cable, but pointed the way to success.

The first American paper on cerebral tumor, by Hirschfelder and Morse, of San Francisco, appeared in the *Pacific Medical and Surgical Journal* for April, 1886. The case was that of the successful localization, but unsuccessful removal, of a brain tumor. Two most remarkable papers on brain surgery, however, were published soon afterward by Mr. Victor Horsley, in the *British Medical Journal* for October 9, 1886, and April 23, 1887. In these papers ten cases were related, all of which were correctly localized; only one died, and the remainder were either benefited or cured. These were in part cases of removal of brain tumor and of portions of diseased brain tissue the cause of epilepsy, and in part cases of trephining for relief of intense headache, etc.

In this country, besides many excellent publications that I have not space or time to enumerate, the most noteworthy early papers published have been those by John B. Roberts, read before the American Surgical Association in 1885; two by R. W. Amidon, in the *Medical News* for January 21, 1884, and the *Annals of Surgery*, vol. i., 1885, both of these authors making strong pleas for early and more heroic surgical interference in affections of the brain; and one by Seguin and Weir, in the *American Journal of the Medical Sciences* for July, August, and September, 1888. I have also published several papers to which I may allude; the earliest two appeared in the *American Journal of the Medical Sciences* for October and November, 1888, and in the *Medical News* for December 1, 1888. In Germany perhaps the most elaborate and important publication is von Bergmann's *Hirnchirurgie*.

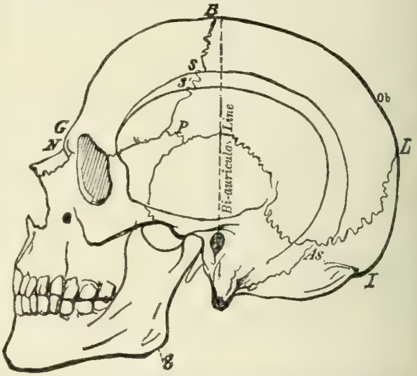

FIG. 995.—Skull Showing Points Named by Broca. *N*, Nasion (junction of the nasal and frontal sutures); *G*, ophryon (on a level with the superior border of the eyebrows, and corresponding nearly to the glabella, the smooth swelling between the eyebrows); *B*, bregma (junction of the sagittal and coronal sutures); *Ob*, obelion (the sagittal suture between the parietal foramina); *L*, lambda (junction of the sagittal and lambdoidal sutures); *I*, inion (external occipital protuberance); the basion is the middle of anterior wall of foramen magnum; *As*, asterion (junction of the occipital, parietal, and temporal bones) *g*, gonion (angle of the lower jaw); *S*, stephanion (or, better, the superior stephanion, intersection of ridge for temporal fascia and coronal suture); *S'*, inferior stephanion (intersection of ridge for temporal muscle and coronal suture); *P*, pterion (point of junction of great wing of sphenoid and the frontal, parietal, and squamous bones). This may be H-shaped, or K-shaped, or "retourné," in which the frontal and temporal just touch.

In addition to these, Mr. Horsley published, in the *British Medical Journal* for June 16, 1888, an account of the removal of a tumor from the spinal cord, and Dr.

Macewen (*British Medical Journal*, August 11, 1888) published six cases in which the posterior arches of the vertebra had been removed for tumor and compression of the cord, and for an abscess in the posterior mediastinum, two of which (paraplegia from Pott's disease and fractured spine) had been published as early as 1886 (*Glasgow Medical Journal*, xxv., 210.) (See article on *Spine, Surgery of the.*) I shall refer in the course of this paper to a number of other publications, but I have thought it right to sketch thus briefly the *early* historical development of the subject.

Two things have made such brain surgery possible. First, the accurate localization of the functions (especially the motor centres) by Ferrier, Horsley, Fritsch, Hitzig, and others, by means of which we can with fair accuracy determine the site of a tumor, abscess, cyst, etc., by the focal symptoms. Secondly, the impunity with which we can trephine and open the dura mater, and interfere with the brain tissue itself, due almost entirely to the introduction of antiseptic surgery. To Horsley more than to any one else we owe the formulation of rules for successful brain surgery—rules which will be given at length hereafter.

The Danger of Trephining.—For the technique of trephining I refer the reader to the paper under that head in a later volume. But it is important further to consider the question of the danger involved in this operation. In St. Bartholomew's Hospital Reports for 1882, Dr. Walsham published a paper entitled "Is Trephining of the Skull a Dangerous Operation *per se?*" In this article he analyzes 686 cases, of which 417 survived, the mortality, therefore, being 39.3 per cent. Dividing these large numbers into classes: first, those in which preventive trephining was used (nearly all for fracture), there being no cerebral symptoms, the mortality was 21.9 per cent.; second, trephining in which severe cerebral symptoms existed, the mortality was 48.4 per cent.; third, trephining in which moderate cerebral symptoms were present, the mortality was 27 per cent.; fourth, late trephining, mostly after inflammation had set in, the mortality was 58.5 per cent.; fifth, secondary trephining showed a mortality of 22 per cent.

Walsham showed that in 122 cases of late trephining, in which there was no condition endangering life, only 10.6 per cent. died. Amidon, in the paper referred to, analyzes 100 cases of trephining reported since 1879, in most of which antiseptics were employed. Of these 100 cases 26 died, but of these 23 presented at the time of operation symptoms already endangering life. He therefore concluded (and most later writers practically concur in his conclusions) that the mortality of trephining *per se* is but 3 per cent., a conclusion which would seem to be confirmed by Prunières and Robert Fletcher, by their investigations, which show the frequency of recovery in cases of prehistoric trephining. Seydel ("Antiseptie und Trepanation") even estimates the mortality as only 1.6 per cent.

Not only have antiseptics thus diminished the danger of simply opening the cranium, but the numerous cases which have been reported of opening the dura, even when followed by removal of tumor or of some brain substance, clearly show that only moderate danger is added in any case by such surgical procedures. "Heretofore," says Amidon, "the reluctance of the surgeon to open the cranium seems avidity as compared with his hesitation in piercing the dura mater. The cerebral cortex seems to be a 'dead line' inside the prison walls of conservative surgery, across which even the most daring are tempted or the most unwilling are dragged only by sure indications or desperate chances."

The future danger seems to be, however, that temerity may take the place of timidity, and that many patients will either die or go about with multilated brains that ought never to have been touched. This word of caution, therefore, at the outset may not be out of place.

TOPOGRAPHY OF THE BRAIN IN ITS SURGICAL RELATIONS.—The relation of the chief fissures and convolutions of the brain to the surface of the skull is of the greatest possible importance. It is essential that we shall be able, from fixed landmarks on the skull, to locate the various fissures and convolutions, and by them the various cortical centres. The subject has been studied by Reid, Horsley and Hare, Krönlein and others, each of whose methods of research has its own merit.

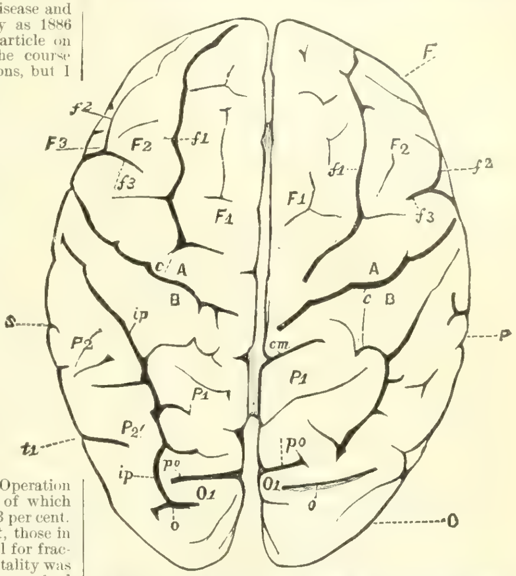

FIG. 996.—View of the Brain from Above. *F*, Frontal lobe; *P*, parietal lobe; *O*, occipital lobe; *S*, end of the horizontal branch of the fissure of Sylvius; *c*, central fissure or fissure of Rolando; *A*, anterior central or ascending frontal convolution; *B*, posterior central or ascending parietal convolution; F_1, upper, F_2, middle, F_3, lower frontal convolution; f_1, superior frontal sulcus; f_2, inferior frontal sulcus; f_3, vertical fissure (sulcus praecentralis); P_1, upper or postero-parietal lobule; P_2, lower parietal lobule, constituted by P_2, supramarginal gyrus; P_2', angular gyrus; *ip*, intraparietal sulcus; *cm*, calloso-marginal sulcus; *po*, parieto-occipital fissure; t_1, upper temporal sulcus; O_1, first occipital convolution; *o*, transverse occipital sulcus. (Ecker.)

I shall give a brief outline of the four methods, and in doing so I must take it for granted that the reader is fairly well acquainted with the chief outlines of the cerebral cortex. In order, however, to facilitate the study of the external topography of the brain, I have introduced cuts.

First: Fig. 995, from Broca, giving the points named upon the skull.

Secondly: Figs. 996–998, from Ecker, giving the names of the principal sulci and convolutions.

I have also appended two figures from Ferrier's "Functions of the Brain" (Figs. 999 and 1000) in order to fix as nearly as possible the relations of the various centres, so far as known at present. The figures in these two cuts are placed as follows:

1, On the postero-parietal lobule (precuneus), the centres for movements of the opposite leg and foot in locomotion. 2, 3, 4, At the upper end of the fissure of Rolando, and hinder part of the first frontal convolution, the centres for various complex movements of the arms and legs, as in climbing, swimming, etc. In this area Horsley states that the arm and leg of the same side are involved together. 5, At the posterior part of the superior frontal convolution—extension forward of the arm and hand, as in putting forth the hand to touch something in front. 6, On the ascending frontal (pre-Rolandic) convolution, just behind the upper and hinder end of the middle frontal convolution—movements of the hand and forearm in which the biceps is particularly engaged, viz., supination of the hand and flexion of the forearm. 7 and 8, Respectively for the elevators and depressors of the angle of the mouth. 9 and 10, As one, mark the centre for movements of the lips and tongue, as in speech. This especially occupies the posterior portion of the inferior frontal (generally known as Broca's) convolution. Disease of this region on the left side produces aphasia. 11,. The centre for the platysma, retraction of the angle of the mouth. 12, A centre for the lateral movements of the head and eyes, with elevation of the eyelids and dilatation of the pupils. 13 and 13′, On the supramarginal lobule and angular gyrus, including also the occipital lobe, indicate the centre for vision. 14, On the superior temporo-sphenoidal convolution, indicates the centre for hearing. *a*, *b*, *c*, *d*, On the ascending parietal (post-Rolandic) convolution, indicate the centres for movements of the fingers and wrist. The centre for smell is situated in the hook of the hippocampal region (Fig. 998, *U*). In close proximity, but not exactly defined as to limits, is the centre for taste. The centre for touch is situated in the hippocampal region (Fig. 998, *H*) and gyrus fornicatus (*Gf*).

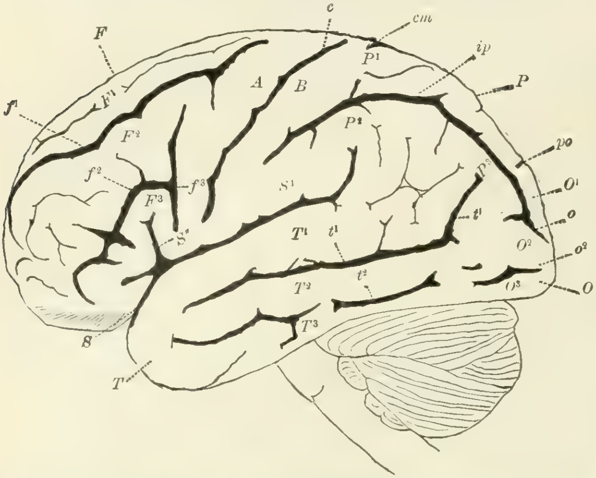

FIG. 997.—Outer Surface of the Left Hemisphere. *F*, Frontal lobe; *P*, parietal lobe; *O*, occipital lobe; *T*, temporo-sphenoidal lobe; *S*, fissure of Sylvius; *S′*, horizontal, *S″*, ascending ramus of the same; *c*, central sulcus or fissure of Rolando; *A*, anterior central or ascending frontal convolution; *B*, posterior central, or ascending parietal convolution; *F*¹, superior, *F*², middle, and *F*³, inferior frontal convolutions; *f*¹, superior, *f*², inferior frontal sulcus; *f*³, præcentral sulcus; *P*¹, superior parietal or postero-parietal lobule; *P*², *P*³, inferior parietal lobule, viz.: *P*², supramarginal gyrus; *P*³, angular gyrus; *ip*, intraparietal sulcus; *cm*, termination of the calloso-marginal fissure; *O*¹, first, *O*², second, *O*³, third occipital convolutions; *po*, parieto-occipital fissure; *o*¹, transverse occipital sulcus; *o*², inferior longitudinal occipital sulcus; *T*¹, first, *T*², second, *T*³, third temporo-sphenoidal convolutions; *t*¹, first, *t*², second temporo-sphenoidal sulci. (Ecker.)

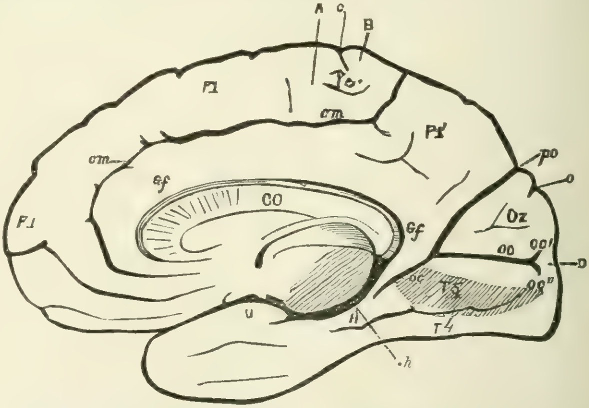

FIG. 998.—Inner Surface of the Right Hemisphere. *CC*, Corpus callosum, longitudinally divided; *Gf*, gyrus fornicatus; *H*, gyrus hippocampi; *h*, sulcus hippocampi or dentate fissure; *U*, uncinate gyrus; *cm*, calloso-marginal sulcus; *F*1, median aspect of the first frontal convolution; *c*, terminal portion of the central sulcus, or fissure of Rolando; *A*, ascending frontal, *B*, ascending parietal convolution; *Pc*, paracentral lobule; *P*1′, precuneus; *Oz*, cuneus; *po*, parieto-occipital fissure; *o*, transverse occipital sulcus; *oc*, calcarine fissure; *oc′*, superior, *oc″*, inferior ramus of the same; *D*, gyrus descendens; *T*4, gyrus occipito-temporalis lateralis (lobulis fusiformis); *T*5, gyrus occipito-temporalis medialis (lobulus lingualis); *cf*, collateral or occipito-temporal fissure. (Ecker.)

To these I also add Figs. 1001 to 1009 from Horsley's article (*Amer. Jour. of the Med. Sciences*, April, 1887) for the same purpose. I also add a figure from Gowers (Fig. 1010) to show the relations of the convolutions to the skull.

The reader desirous of further information will find it briefly stated in the American edition of Gray's "Anatomy," for 1887, p. 681, or very fully in the works of the authors already referred to, together with Ferrier's "Functions of the Brain." (See also article *Skull*, etc.)

It must be borne in mind that, as pointed out by Stokes, the relations between the brain and the skull vary at different ages, a fact reinforced by Cunningham's models of the brain hardened *in situ*, and then exposed by removing the bones of the skull, leaving bridges at the sutures. Symington points out that the Sylvian fissure lies much higher above the squamo-parietal suture in the child than in the adult, and is from half an inch to even an inch above it. He thinks that they attain the adult relations at about the eighth or ninth year.

The fissure of Rolando is also much more oblique in its direction (52°, Hamy) in the child, and lies farther forward on account of the imperfect development of the frontal lobes. Gradually as these are developed, especially the third frontal convolution, the lower end of the fissure is pushed back and assumes its adult angle and position.

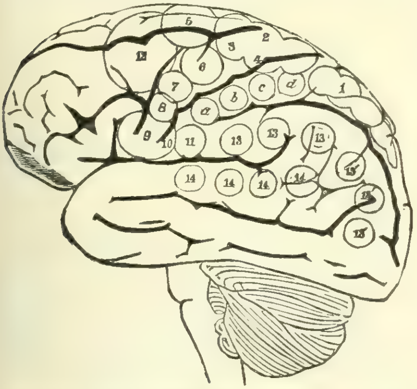

FIG. 999.—Side View of the Brain of Man. (Ferrier.) (For references see pp. 399, 400).

First: *Landmarks on the Skull.* Most of these are readily determined by reference to the foregoing figures, but there are some which must be more minutely described.

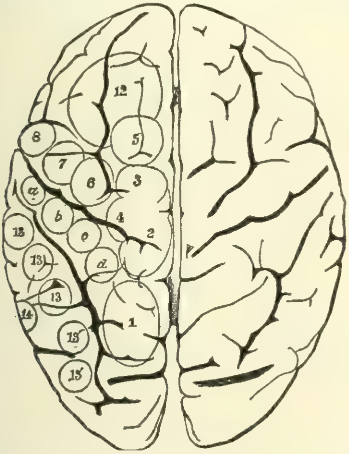

FIG. 1000.—Top View of the Brain of Man. (Ferrier.) (For references see pp. 399, 400.)

The *temporal ridges* (Fig. 995) are two in number: the upper for the temporal fascia, the lower for the upper border of the temporal muscle. The upper is the better marked, and can be easily followed by the finger from the external angular process backward. It marks the sudden change in the slope of the skull, from the curve of the upper surface to the more vertical direction of the side. The lower one is best made out by closing and relaxing the jaw, when the upper edge of the temporal muscle can be located by the finger. Like the upper, it begins at the external angular process, but runs at a lower level than the fascial ridge. Its middle is about two-fifths of an inch below it. The points where the coronal suture crosses these two ridges are called respectively the upper and the lower stephanion (Fig. 995, *S* and *S*′).

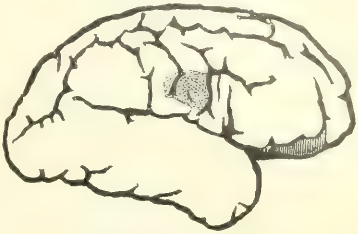

FIG. 1001.—Representation of the Centre for the Upper Face and Angle of the Mouth. (Horsley.)

The *coronal suture* starts at the bregma (Fig. 995, *B*).

Drawing the bi-auricular line (Fig. 995), measurements on 185 skulls have given me as a mean result, that in the adult the *bregma* lies 0.375 of an inch in front of this line. The greatest distance was 1.2 inch. In 16 of these skulls, the bregma coincided with the point where the bi-auricular line crosses the sagittal suture. In only 7 did it lie behind it, the maximum being 0.9 inch. Starting from the bregma, by shoving the scalp backward and forward, the finger can perceive (but with some difficulty, especially in the aged) the irregularities of the coronal suture, but toward the stephanion they become more marked and can be pretty well appreciated. The *parieto-squamosal*

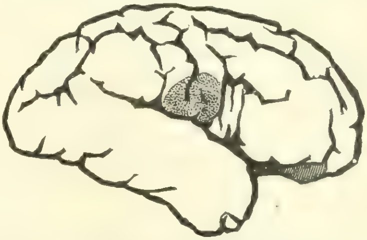

FIG. 1002.—Representation of the Centre for the Vocal Chords (Adduction). (Horsley.)

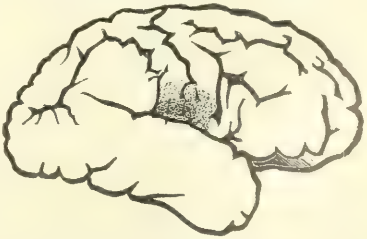

FIG. 1003.—Representation of the Centre for the Lower Face and Floor of the Mouth. (Horsley.)

suture lies beneath the temporal muscle. The highest point of its curved line is at the junction of the upper and middle thirds of a vertical line drawn from the upper border of the zygoma to the ridge for the temporal muscle in front of the temporo-maxillary articulation.

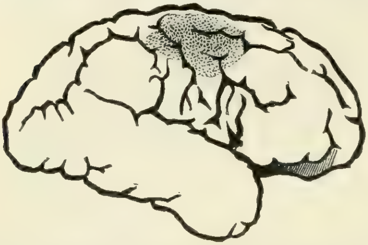
FIG. 1004. Representation of the Centre for the Shoulder. (Horsley.)

The point of junction of the great wing of the sphenoid, frontal, parietal, and squamous bones is called the *pterion* (Fig. 995), and is about half-way between the superior stephanion and the zygoma. It is usually H-shaped.

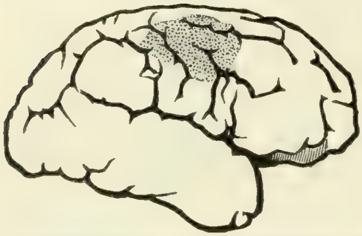
FIG. 1005.—Representation of the Centre for the Elbow and Wrist. (Horsley.)

The Relation of the Fissures and Convolutions to the Landmarks on the Skull.—There are five great fissures of the brain to be localized:

First, the *great longitudinal fissure* separates the two hemispheres of the cerebrum. This does not lie precisely in the middle line, but in consequence of the slightly larger size of the left hemisphere, it lies about an eighth of an inch to the right of the middle line.

Second, the *great transverse fissure*, or the fissure of Bichat, between the cerebrum and the cerebellum. This lies in a line from the external auditory meatus to the *inion* (or external occipital protuberance). This marks also the position of the tentorium and of the lateral sinuses. The other three great fissures (viz., the *fissure of Sylvius*, the *fissure of Rolando*, and the *parieto-occipital fissure*) may be located by the following rules.

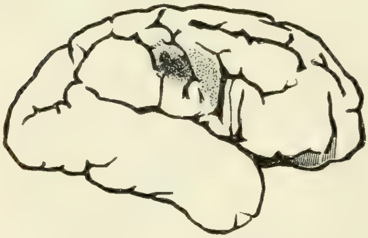
FIG. 1006.—Representation of the Centre for the Thumb. (Horsley.)

Horsley's Method.—The *fissure of Rolando*, in relation to the motor region, is the most important in the whole brain. As will be seen by reference to Figs. 996 and 997, almost all the motor centres lie clustered about it. As Thane has shown, it runs downward and forward from a point half an inch behind the middle of the distance from the glabella to the inion. This point being fixed, if a line be drawn laterally at an angle of 67° (as shown by Hare) for a distance of three and three-eighths inches, it will indicate the fissure of Rolando; the lower third of the fissure, however, changes to a somewhat more vertical direction, thus forming a knee-like bend. To fix this important fissure, Horsley uses a strip of metal or of parchment paper, say fourteen inches long, with a second strip firmly fixed to it at an angle of 67° (Fig. 1011).

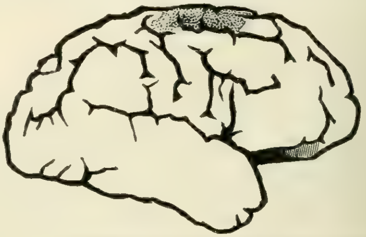
FIG. 1007.—Representation of the Centre for the Combined Synchronous Action of Both Limbs. (Horsley.)

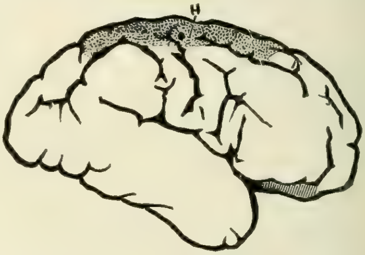

FIG. 1008.—Representation of the Centre for the Lower Limb. H, Focus of representation of the hallux. (Beevor and Horsley.)

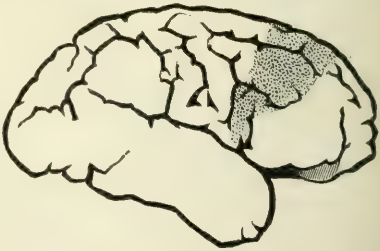
FIG. 1009.—Representation of the Centre for the Head and Neck, together with Conjugate Deviation of the Eyes. (Horsley.)

The zero point of the scale of the longer piece (as suggested by Dr. Morris J. Lewis, of Philadelphia) is placed half an inch in front of the angle formed by the two arms. From this zero point the scale (in quarter inches) leads both forward and backward. The longer arm is placed in the middle line of the shaven head, in such a position that the reading of the two scales at the glabella and at the inion shall be identical. The lateral strip will then mark the fissure of Rolando (three and three-eighths inches); the direction of the lower third being slightly changed, as above indicated.

The *fissure of Sylvius* commences at the pterion, the anterior branch running upward and forward, continuing the line of the squamo-sphenoidal suture, but one or two millimetres in front of it. The posterior branch passes upward and backward half a millimetre above the squamo-parietal suture, as far as its highest point, and from there curves slightly upward toward the centre of the parietal eminence, which it nearly reaches. This fissure limits the motor region anteriorly by its anterior limb, and postero-inferiorly by its posterior limb.

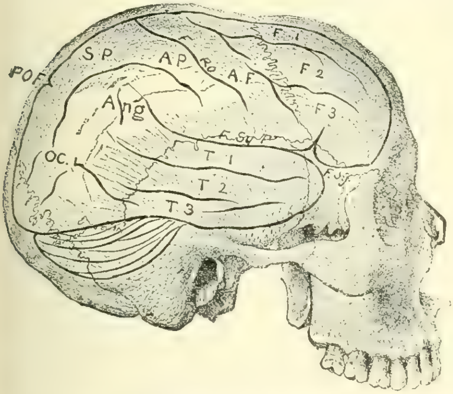

FIG. 1010.—Diagram of the Relations of the Convolutions to the Skull. *F* 1, 2, and 3, Upper, middle, and lower frontal convolutions; *A F*, *A P*, ascending frontal and parietal convolutions; *S P*, superior parietal lobule; *Ang*, angular gyrus; *OcL*, occipital lobe; *T* 1, 2, 3, the temporal convolutions; *P O F*, parieto-occipital fissure; *F Sy* and *F Sy P*, fissure of Sylvius and its posterior limb; *F. Ro*, fissure of Rolando. (Gowers.)

The *precentral* or *vertical sulcus* is of great importance also, as it divides two convolutions of very different functions, and on each side of it has convolutions of great motor importance. It runs parallel to and just behind the coronal suture, and is almost vertical to a horizontal tangent at the bregma; hence its second name. Its upper end reaches to the level of the middle of the fissure of Rolando. From it, about on a level with the superior stephanion, the *inferior frontal sulcus* runs forward. Above the origin of this latter sulcus, the precentral sulcus continues vertically half-way across the root of the middle frontal convolution. Its lower end is separated from the fissure of Sylvius by a horseshoe-shaped convolution of great importance (the *operculum*), which is nearly always one centimetre wide, and overlies the island of Reil.

The *superior frontal sulcus* starts from the ascending frontal (pre-Rolandic) convolution midway between the fissure of Rolando and the line of the precentral sulcus. Its posterior end, therefore, lies behind the precentral sulcus. The superior and inferior frontal sulci run forward and slightly downward, practically parallel with the great longitudinal fissure.

The *intraparietal sulcus* lies behind the fissure of Rolando, and bounds the motor area posteriorly. It begins opposite the knee-like bend at the junction of the middle and lower thirds of the fissure of Rolando. As it goes upward it lies about midway between the line of the Rolandic fissure and the parietal eminence. It then separates farther from the fissure of Rolando, and so widens the area of the ascending parietal (post-Rolandic) convolution that its upper end is known as the *superior parietal lobule.* In the middle of its course it runs about parallel to the great longitudinal fissure, and midway between it and the parietal eminence. Farther on, it passes by the external end of the parieto-occipital fissure and goes downward and backward into the occipital lobe.

The *parieto-occipital fissure* on the upper surface of the cerebrum is a short fissure about an inch long, at right angles with the great longitudinal fissure, and two or three inches in front of the *lambda* (the junction of the lambdoidal and sagittal sutures) (Fig. 995, *L*). This fissure, on the median surface of the cerebrum (Fig. 998, *po*), is a long fissure running downward and forward. It is joined at its middle by the *calcarine fissure* (Fig. 998, *oc*). Between these two fissures is the *cuneus* (*Oz*, Fig. 998), in which lies the cortical centre for sight. Injury to the cuneus, therefore, produces blindness in the half of each retina on the side corresponding to the injury (hemianopsia).

In front of the parieto-occipital fissure, on the middle surface of the hemisphere, lies the *precuneus* or *quadrate lobule* (Fig. 998, P_1'), bounded in front by the upper end of the *calloso-marginal fissure* (*cm*).

In front of and behind the fissure of Rolando (Figs. 997 and 998) are two most important convolutions. The one in front is chiefly known as the ascending frontal or precentral, or, as I prefer to term it, the *pre-Rolandic convolution.* The one behind the fissure of Rolando is known as the ascending parietal or postcentral, or, as I prefer to term it, the *post-Rolandic convolution.* At their upper ends they fuse into the *paracentral lobule*, and at their lower into the *operculum.* The two frontal sulci divide the frontal lobe horizontally into three convolutions, viz., the first, second, and third, or respectively the *superior, middle,* and *inferior frontal* convolutions. The third or inferior convolution is frequently known as *Broca's convolution.* On the left side the *centre for speech* is located (in left-handed persons this speech centre lies in Broca's convolution on the right side). For the location of other centres in these various convolutions the reader is referred to Figs. 999–1009.

Below the intraparietal sulcus, between its beginning and the posterior limb of the fissure of Sylvius, lies the *supramarginal convolution* (Fig. 997, P^2). Below the posterior portion of the intraparietal, and behind the superior extremity of the horizontal limb of the Sylvian fissure, lies the *angular gyrus* (Fig. 997, P^3).

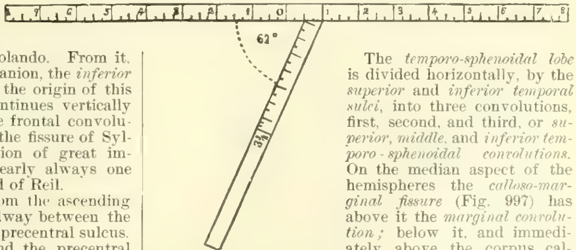

FIG. 1011.—Horsley's Instrument for Fixing the Fissure of Rolando, as Modified by Dr. Morris J. Lewis.

The *temporo-sphenoidal lobe* is divided horizontally, by the *superior* and *inferior temporal sulci*, into three convolutions, first, second, and third, or *superior, middle,* and *inferior temporo-sphenoidal convolutions.* On the median aspect of the hemispheres the *calloso-marginal fissure* (Fig. 997) has above it the *marginal convolution;* below it, and immediately above the corpus callosum, lies the *gyrus fornicatus.*

Reid's Method.—Reid's "base line" (Fig. 1012) is a line running backward from the infra-orbital ridge through the middle of the external auditory meatus, and prolonged to the middle line of the head posteriorly. The *fissure of Sylvius* runs from a point an inch and a quarter behind the external angular process of the frontal bone to a point three-fourths of an inch below the most prominent point of the parietal eminence. Measuring from above backward, the first three-fourths of an inch will represent the main fissure; the rest indicates the horizontal limb. The ascending limb starts at a point three fourths of an inch back of the anterior extremity, that is, two inches behind and slightly above the external angular process, and runs vertically upward and forward about one-fourth of an inch

To find the *fissure of Rolando*, draw the base line and the lines for the great longitudinal fissure and the fissure of Sylvius. Then draw two lines perpendicular to the base line: one from the depression in front of the external meatus (Fig. 1012, D E) and the other (F G) from the posterior border of the mastoid process at its root. We shall thus have on the surface of the head a four-sided figure, bounded above and below by the lines for the longitudinal fissure and the horizontal limb of the fissure of Sylvius, respectively, and in front and behind by the two perpendicular lines just described. Next draw a diagonal line (F H) from the posterior superior angle to the anterior inferior angle. This corresponds to the fissure of Rolando, which, however, as a rule, does not quite join the fissure of Sylvius.

Cunningham states, however, that this (Reid's) mode of locating the fissure of Rolando is not reliable, and I much prefer Horsley's, Krönlein's, or Hare's, both as more accurate and much more easily applied.

To find the *parieto-occipital fissure* continue the line for the horizontal limb of the fissure of Sylvius (Fig. 1012, *Sy.h.fis.*) to the line of the longitudinal fissure. The portion of this line, about an inch long, next to the longitudinal fissure, will usually approximately correspond to it. The position of the various convolutions can now be readily indicated by reference to Fig. 1010.

Hare's Method.—Mr. A. W. Hare has pointed out that neither the cranial sutures nor the prominences of the face are available for mapping out the brain; the former, because they are too indistinct or obliterated, the latter, because they have no direct relation to the cranium as a whole on account of the unequal development. The same observation, he points out, is true of the bony landmarks on the lower portion of the skull. If the external auditory meatus or the mastoid process has lines drawn from it over the convexity of the skull, they will give inconstant results according as the anterior or posterior portions of the head are more or less developed. Four points, however, are of value, viz., (1) the glabella, which corresponds to the base of the anterior lobe of the brain; (2) the inion, which corresponds to the base of the posterior lobe of the brain, and also to the junction of the falx with the tentorium; (3) the third constant landmark is the external angular process of the frontal bone which limits the cerebrum laterally and has also a uniform relation to the fissure of Sylvius; (4) finally, the parietal eminence is valuable, since it marks the greatest lateral expansion of the brain and bears a special relation to the supramarginal convolution. While its cranial relations vary considerably, its cerebral relations are much more constant. The distance from the glabella to the upper end of the *fissure of Rolando* will be 55.7 per cent. of the total distance from the glabella to the inion. For instance:

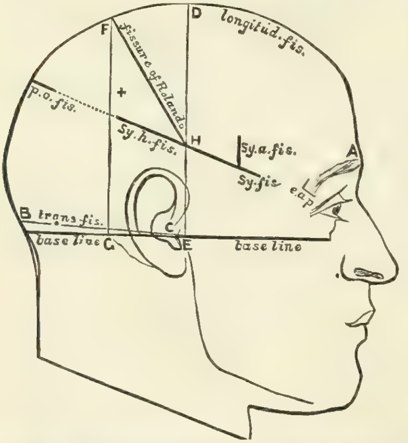

FIG. 1012.—A, Glabella; B, external occipital protuberance; *e.a.p.*, external angular process of frontal bone; B C, transverse fissure; A B, longitudinal fissure; *Sy.fis.*, Sylvian fissure; *Sy.h.fis.*, horizontal limb of fissure of Sylvius; *Sy.a.fis.*, ascending limb of fissure of Sylvius; D, E, perpendicular line from depression in front of external auditory meatus to middle line of top of head; F, G, perpendicular line from posterior end of base of mastoid process to middle line of top of head; F, H, fissure of Rolando; *p.o.fis.*, parieto-occipital fissure; +, most prominent part of parietal eminence. (Reid.)

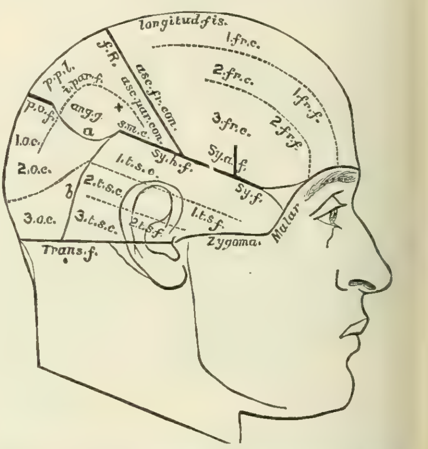

FIG. 1013.— +, Most prominent part of parietal eminence; *a*, convex line bounding parietal lobe below; *b*, convex line bounding temporo-sphenoidal lobe behind; 1.*fr.c.*, first frontal convolution; 1.*fr.f.*, first frontal sulcus; *f*.R, fissure of Rolando; *Sy.f.*, Sylvian fissure; *Sy.h.f.*, horizontal limb of Sylvian fissure; *Sy.a.f.*, ascending limb of Sylvian fissure; *p.o.f.*, parieto-occipital fissure; *i.par.f.*, intraparietal sulcus; *ang.g.*, angular gyrus; *s.m.c.*, supramarginal convolution; 1.*t.s.c.*, first temporo-sphenoidal convolution; 1.*t.s.f.*, first temporo-sphenoidal sulcus; 1.*o.c.*, first occipital convolution; *p.p.l.*, postero-parietal lobule. (Reid.)

If the distance from the glabella to the inion is—	The distance from the glabella to the upper end of the Rolandic fissure will be—
11 inches.	6.1 inches.
11½ "	6.4 "
12 "	6.6 "
12½ "	7.0 "
13 "	7.2 "

In other words, however the proportions of a head may differ, the pre-Rolandic and post-Rolandic regions of the brain are uniformly proportionate to each other, the pre-Rolandic being 55.7 per cent. and the post-Rolandic 44.3. Moreover, the fissure of Rolando runs downward and forward at an angle of 67°, and its average length is 3⅜ inches.

Dr. Claude Wilson, of Tunbridge Wells, has constructed a cyrtometer (Fig. 1014) consisting of two strips of flexible metal forming a letter **T**, with a tape to secure the short horizontal limb in place; the mode of using which is shown in Fig. 1015. On the antero-posterior arm it will be noticed that there are two scales. The posterior scale is lettered in *capitals* from A to Q. The anterior scale is lettered in *small letters* from *a* to *q*, and they are so placed that when in position the distance from the glabella to small *a*, *b*, *c*, etc., is 55.7 per cent. of the distance from the glabella to capital A, B, C, etc. The horizontal limb being placed on the forehead, so that its inferior border corresponds to the glabella, if the capital letter A falls over the inion, then the small *a* will correspond to the beginning of the fissure of Rolando, and so on for the other letters. The small strip for marking the fissure of Rolando is movable on the antero-posterior limb, and is also reversible to suit both sides. This is now slid along until it corresponds for instance to the small *a*, when its anterior border marks the line of the fissure of Rolando. Similarly, if the inion corresponds to B or C, the Rolandic strip is slid to *b* or *c*, etc.

The Fissure of Sylvius.—To locate this fissure a line is drawn from the external angular process backward to the occipital protuberance (Fig. 1018, EAP to OPr) by the *shortest route* between these points. This line droops a little toward the external auditory meatus in avoiding the great convexity of the skull, which convexity lies in the course of the *direct horizontal* line between these two bony prominences. It usually passes about half an inch above the meatus, and thus closely corresponds to the floor of the middle fossa at this point. In front of the meatus it lies above the level of the floor of the middle fossa; behind it, it runs parallel to, and nearly coincident with, the attachment of the tentorium and the posterior half of the lateral sinus. A point one inch and a half posterior to the external angular process on this line marks the commencement of the fissure of Sylvius. Even in heads of the most varied shapes and sizes this measurement remains constant. From this point a straight line to the centre of the parietal eminence marks accurately the course of the posterior limb of the fissure and nearly corresponds in part with the squamo-parietal fissure (Fig. 1018, SF). The ascending limb of the fissure corresponds closely with the squamo-sphenoidal suture in its entire length, and is continued upward in the same line for half an inch (A). The middle meningeal artery is also shown in Fig. 1018 in its relation to the Sylvian and Rolandic fissures. To expose the tip of the temporo-sphenoidal lobe, trephine behind the upper extremity of the great wing of the sphenoid (TS). To expose Broca's convolution, trephine immediately in front of the great wing of the sphenoid (B).

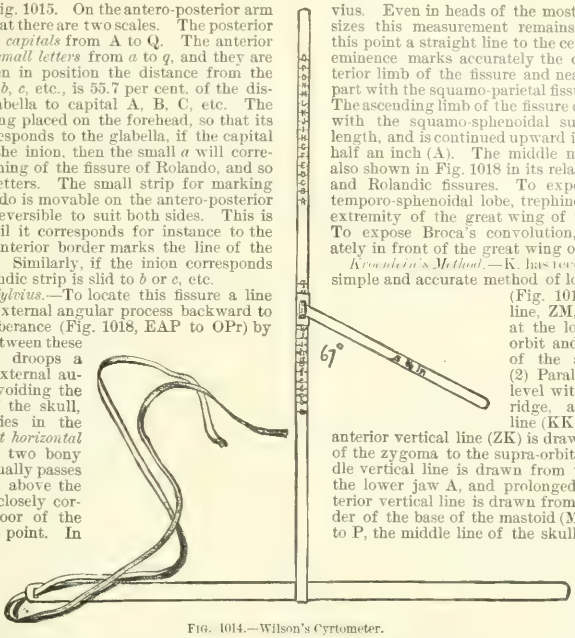

FIG. 1014.—Wilson's Cyrtometer.

Kronlein's Method.—K. has recently proposed this simple and accurate method of locating the fissures (Fig. 1016): (1) The base line, ZM, runs horizontally at the lower border of the orbit and the upper border of the auditory meatus.[*] (2) Parallel with this, on a level with the supraorbital ridge, another horizontal line (KK') is drawn. (3) An anterior vertical line (ZK) is drawn from the middle of the zygoma to the supra-orbital line. (4) A middle vertical line is drawn from the articulation on the lower jaw A, and prolonged to R. (5) A posterior vertical line is drawn from the posterior border of the base of the mastoid (MK') and prolonged to P, the middle line of the skull. (6) Draw a line from K to P. Between the points R and P' it corresponds to the fissure of Rolando. (7) Bisect the angle PKK' by the line KS. This line corresponds to the fissure of Sylvius from its bifurcation to its posterior end. The point K is over the bifurcation of the fissure of Sylvius. K and K' are the points for trephining to reach the anterior and posterior branches of the middle meningeal artery. The method applies equally to all varieties in the shape of the head, both brachi- and dolicho-cephalic.

Chiene's Method.—Mr. John Chiene, of Edinburgh, has proposed a method of fixing the position and length of the Rolandic fissure which is at once simple, ingenious, and always available. He folds a square piece of paper once (Fig. 1017, A, B, C, D), on the diagonal line A, C. The angle B A C is then evidently 45°. The angle D A C (45°) is then halved (22.5°) by folding the paper again on the line A E. The sum of the angles B A C and C A E

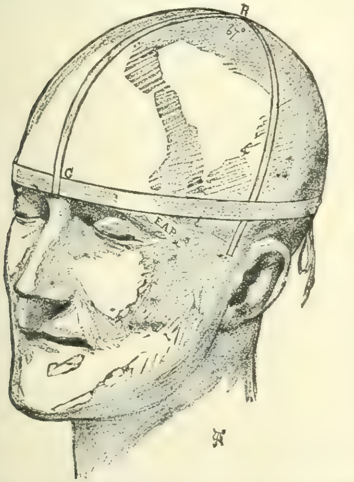

FIG. 1015.—Wilson's Cyrtometer *in situ*. G, Glabella; EAP, external angular process; R, fissure of Rolando, its position and direction marked by the lateral strip of metal.

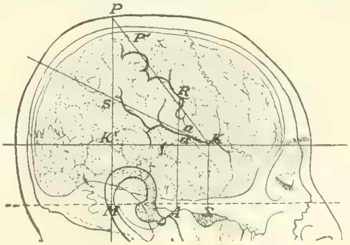

FIG. 1016.

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[*] I perhaps ought to state here that in different parts of this article I have utilized to a small extent portions of the text contributed to other publications.

is evidently 67.5°, which is near enough for all practical purposes to the angle of the fissure of Rolando. The side A B is then applied to the middle line of the head, the point A being placed half an inch behind the midpoint between the glabella and the inion, when the line A E will correspond to the fissure of Rolando.

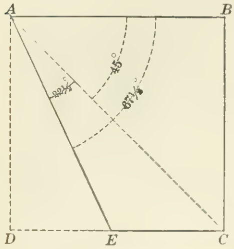

FIG. 1017.—Chiene's Method of Locating the Fissure of Rolando.

But it must be remembered that however exact our cerebral localization may be, there are exceptional cases that set at naught all our present knowledge on this subject. Thus Cunningham reports a case of subarachnoid cyst extending from the fissure of Rolando to the occipital lobe with neither motor nor sensory disturbance, and Bramwell reports a case of sarcoma of the dura destroying the greater part of the motor centre without any paralysis. These and a number of other such cases should make us careful not to be too dogmatic until we learn much more.

Percussion of the Skull.—Here, perhaps, as well as elsewhere, may be noted a point to which Macewen has called attention, viz., that percussion of the skull may afford valuable evidence not only of the condition of its contents, and, as I have pointed out, of that of the skull itself, but also, as I have observed in one case, of the condition of the overlying tissues.

Macewen does not state the character of the percussion note, but presumably it is that, when an abscess or tumor exists, there will be a local, increased dulness on percussion, with a lower tone. He states that it has been verified post mortem, and that it will probably be of especial value in early life in the diagnosis of tumors of the cerebellum. In a case of hydrocephalus I have observed a markedly increased dulness of one side on percussion, and the autopsy showed that the ventricular distention was far more marked on this side.

In simple fracture of the skull, hydrocephalus, and large tumors, the "cracked-pot" sound described on page 421 of this paper may be of service, and I would urge that it be tested and reported on in future cases.

In a case of syphilitic necrosis of the skull above the left ear, with a Jacksonian epilepsy in the left arm and leg, and therefore a presumable lesion (gumma?) on the right side of the brain, I have tested the percussion note. Over the necrosed bone the tissues were somewhat thickened, but not to any excessive degree. The percussion note was so much duller on the left side, half-way between the sagittal suture and the ear, that two of my assistants with their backs turned to the patient correctly stated which side was percussed, and the same difference was noted as between the same site and the forehead well above the frontal sinus. In a paper published in 1884, I have pointed out the similar value of percussion in the so-called abscess in the frontal sinus and the antrum.

GENERAL TECHNIQUE OF OPERATIONS ON THE BRAIN.—This has been carefully formulated by Horsley. In a few minor points I have added to it from my own personal experience, as well as from that of others.

I. *Shaving the Head.*—This is not only important for the operation, but should always precede a definite diagnosis, and, in fact, be one of the means of making it. So important do I regard this that I should consider no diagnosis as assured, and no operation warranted, that had not been preceded by shaving. The unexpected and the unknown scars found have surprised me in several cases. Besides this, no reliable mapping on the head of the fissures and convolutions can otherwise be made. These should always be marked on the skull by an aniline pencil.

II. *Antiseptic Preparation of the Patient.*—The day before the operation the patient's head should again be shaved, scrubbed by a nail-brush with soap and water, next with ether, and then be covered with a wet sublimate dressing (1:2,000), retained in place by a bandage till the time of operation. Formerly I used, as Horsley advises, a solution of 1 to 1,000, but I have found that the recently shaved scalp is so tender that pustulation was often caused by it. This scrubbing must be gentle, but thorough. The operation room should be uncarpeted and should contain only necessary furniture, the walls and ceiling should be carefully wiped the day before, and all the woodwork and furniture scrubbed with carbolic solution. Aseptic gauze sponges should be used. The instruments may be disinfected either by boiling for fifteen minutes, or by lying for an equal length of time in a carbolic solution (1 to 20), and then transferred to boiled water sufficiently cooled to permit of their being handled. The head should be washed with soap and water, ether, and sublimate solution, a second time just before the operation. The hands, and especially the finger nails, of the operator and of every one of the assistants should be most carefully cleaned and then disinfected.

III. *Anæsthetic.*—Horsley specially advises the use of chloroform, but I have often used ether and found no reason to regret it. Horsley cautions us that when the dura is opened there is a special sensitiveness to the action of an anæsthetic (chloroform only?), and that special care should therefore be used not to give too much.

As a preliminary Horsley advises that a quarter of a grain of morphine be injected under the skin from a half-hour to an hour before the operation, both because a smaller quantity of anæsthetic will be required, and also because it produces contraction of the arterioles, and consequently diminishes hemorrhage. As Nancrede has pointed out, however, the use of opium, at least in cases in which a small definite cortical centre is to be removed and but little hemorrhage is anticipated, is not advisable. Horsley states that it is dangerous to operate upon pa-

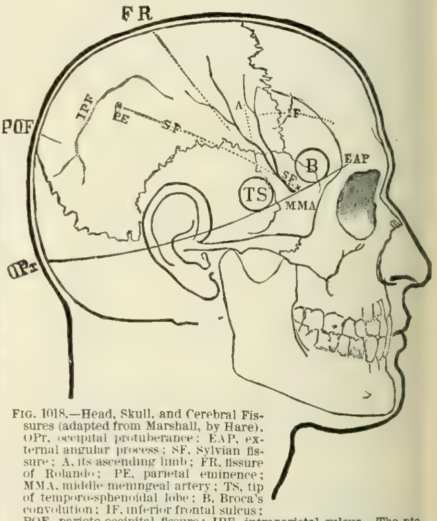

FIG. 1018.—Head, Skull, and Cerebral Fissures (adapted from Marshall, by Hare). OPr, occipital protuberance; EAP, external angular process; SF, Sylvian fissure; A, its ascending limb; FR, fissure of Rolando; PE, parietal eminence; MMA, middle meningeal artery; TS, tip of temporo-sphenoidal lobe; B, Broca's convolution; IF, inferior frontal sulcus; POF, parieto-occipital fissure; IPF, intraparietal sulcus. The pterion is the region where three sutures meet; those bounding the great wing of the sphenoid where it joins the frontal, parietal, and temporal bones.

tients under the influence of drugs, and especially the bromide of potassium; why, I do not know; but I should be inclined to follow so high an authority.

IV. *Marking the Bone.*—This can be done in two ways: 1. The site of the scar or other lesion is easily marked by making a small incision down to the bone and then marking it by an aniline pencil as done by Weir; or, better, I think, as I have proposed, by nicking the bone by a gouge. To mark the Rolandic and other fissures of the brain, the same method may be employed by means of two or more small nicks. These nicks may also be useful in other ways. In my first case (tumor), as I was not able to replace the button of bone, I utilized the nick to fix accurately the location of the tumor. There was a scar, the situation of which was exactly determined by measurements. A nick on the button of bone was made at the site of the scar. After the operation the button of bone was fitted to the tumor, and the dimensions of the tumor measured from the nick. These measurements were afterward transferred to another skull, upon which the site of the scar was accurately fixed, and upon which, also, the fissures of the brain had been marked. I was thus able to locate, with great accuracy, the position of the tumor. 2. Another method of marking the fissures (especially the Rolandic) is by drawing them on the scalp with an aniline pencil, and prolonging the lines above and below the limits of the intended flap. When the flap is raised all the other external landmarks are practically lost; but a nick in the bone, or an imaginary line adjoining the aniline lines of the Rolandic fissure beyond the limits of the flap, will give us this important landmark.

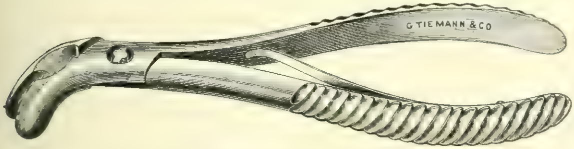

FIG. 1019.—Hopkins' Rongeur Forceps, as Modified by Weir.

V. *Access to the Brain.*—Instead of the old crucial incision Horsley has recommended a large horseshoe-shaped flap, which will usually be about three inches or more in diameter. This incision must be carried vertically down to the skull, and must be so made, first, as to favor drainage in the supine position; secondly, its base should be so placed as to retain the most favorable blood supply to the flap. Horsley has recommended that the periosteum be not raised with the flap, but reflected by a later crucial incision. I have, however, always reflected the periosteum with the flap, and have found no ill results. It is a cardinal principle in the new cerebral surgery that both the flap in the scalp and the opening in the bone shall be ample. The mode of dealing with the bone will be mentioned later; but let it once for all be stated that a large opening in the bone has been amply proved to be no more dangerous than a small one, and an immense advantage can be gained in locating the fissures and the convolutions (and therefore the lesions), and, so to speak, in the amount of "elbow-room" for operative procedure. This is of the greatest possible service. Jonnesco and Doyen have gone so far as to reflect nearly the whole side of the skull (hemicraniotomy). As a rule this is a needlessly large opening and certainly increases the danger.

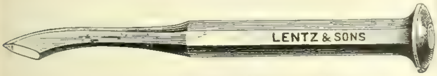

FIG. 1020.—Pyle's Chisel, as Modified by Keen.

Different methods may be adopted for making the opening in the bone. A large trephine, one and one-half, two, or even two and one-half inches in diameter, may be used. If the smallest of these sizes be used, it may necessitate the removal of two adjacent buttons, and even then the opening may have to be enlarged in any given direction for access to the lesion. This is best done by the ordinary rongeur forceps, or by Hopkins' modification of them. These forceps have been further modified (and I think with advantage) by Weir, by making the bend at right angles to the handles of the forceps instead of in their plane (Fig. 1019).

Another method is one that Mr. Horsley has used, and which has the advantage of abridging the time required for the operation. He makes a one-inch opening with a trephine, and by this determines the thickness of the skull. He then outlines the piece of bone to be removed, by Bonwill's surgical engine, cutting almost through the bone. Complete division of the bone is then effected by stout bone forceps. Devilbiss' forceps are also very useful.

The German surgeons frequently use the chisel and hammer. In most of my recent operations I have used this method and have found no evil consequences from their use. Pyle chisels, as modified by myself, I have found the most useful (Fig. 1020). The thick handles add greatly to the convenience of their use.

Oteoplastic Resection.—In 1889 Wagner, following an earlier suggestion of Wolff, proposed to make a temporary osteoplastic resection by chiselling loose the piece of bone to be removed, except at one portion where it was fractured and turned back using the scalp as a hinge. The scalp is incised down to the bone, the flap not being loosened from the bone. By mallet and chisel the bone is then nearly cut through at every point, the separation being completed by an osteotome, excepting at its base. It is then lifted by means of elevators, the base being fractured, a window, so to speak, being opened by turning back the flap (Fig. 1021). By this means access can be had to a very large area of the brain cortex; one of even three, four, or five inches has been thus exposed. When the operation is terminated the opening is closed by replacing the flap, which is sutured in place as usual. In chiselling such a piece loose, it is best to chisel it obliquely, so that the opening in the inner table will be a little smaller than that in the outer, the inner table thus forming a shelf on which the flap rests. The base of the flap which serves as a hinge should always be in that part of the flap having the largest blood supply.

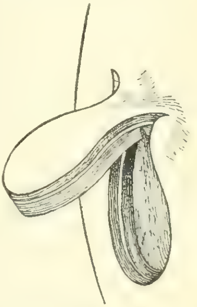

FIG. 1021.

The surgical engine with a special drill, an electrical motor with a saw, and the Gigli wire saw have been also used in place of the chisel.

"Trephining," in the remainder of this paper, will be used in the sense of opening the skull to obtain access to its interior, irrespective of whether the opening is made by the trephine, the chisel, or any other means.

Of course, in trephining for abscess only a three-fourth-inch trephine would be necessary, and the opening can be enlarged, if necessary, by the rongeur forceps. For tapping the ventricles a half-inch opening is ample. Von Bergmann has declared himself opposed to operative interference with a cerebral tumor which would require a large opening in the bone, on account of the probable consequent œdema. The best answer to this is that success has practically followed operations in which large openings have been made and no œdema has followed. Horsley has thus successfully removed a tumor of four and a half ounces, and I have done the same in a case of a tumor weighing over three. Bramann has successfully removed a tumor weighing nine ounces, the largest on record (*Centralbl. f. Chir.*, 1892, Beilage, p. 66). Indeed, in some cases pre-existing œdema has been relieved.

It is quite surprising how far beyond the limit of the opening in the bone and dura we can feel and see. The brain allows gentle pressure very readily. A finger can be inserted for nearly an inch all round the opening, and the eye can reach as far if the brain be gently depressed by any flat instrument.

Before enlarging the opening the dura mater must be separated from the bone. This can be done with a bent probe, but the best instrument is one devised by Horsley (Fig. 1002). By it also the under surface of the surrounding bone can be examined for any inequalities, etc.

The dura, as a rule, should be opened. Unless this is done important information may be lost, and the case be improperly treated. Occasionally it may be allowed to remain intact, when, for instance, a sufficient lesion has been discovered. But it is a rule, with rare exceptions, that, if we trephine at all, the *brain itself* should be examined. The opening in the dura should not be by a crucial incision (except in case of a small opening for abscess of the brain or draining the ventricles), but by a horseshoe-shaped incision at about a quarter of an inch away from the margin of the bony opening. The dura should first be lifted by a tenaculum and slightly opened by a scalpel, and the incision then be completed by a pair of blunt-pointed curved scissors. The dura should be carefully lifted by forceps so as not to wound the veins beneath, and the same caution applies to the scissors. Should it be necessary to cut across the trunk or any branches of the meningeal arteries, they should be secured by ligatures passed through the dura mater by a small curved Hagedorn needle, and tied before the vessel is cut across, the dura being well lifted meantime, lest the needle wound the large veins in the brain. When the operation is terminated, if the dura has not been removed, it should be replaced and secured by catgut.

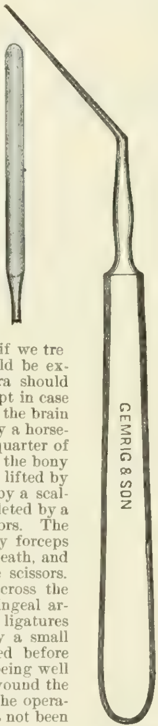

FIG. 1002. Horsley's Instrument, to Separate the Dura from the Skull.

VI. *Hemorrhage.*—Hemorrhage from the scalp will be very free. To a large extent it can be prevented in many cases by the use of the narrow band furnished with Esmarch's bandage, as has been suggested by Dr. M. Allen Starr. Hæmostatic forceps, however, can with safety grasp the entire thickness of the scalp and quickly control any large vessels. Such as need it, of course, should be ligated at the end of the operation. The control of hemorrhage from the vessels of the brain itself, is one of the most difficult of all the operative questions. I have already alluded to the use of morphine. I have also used a solution of cocaine applied directly to the brain. I have also suggested the use of antipyrin, which has been employed by Park with advantage. Such solutions, together with the corks and the bottles, should be sterilized. These applications have certainly proved advantageous in checking hemorrhage from the smaller vessels, nor could I see any harm resulting from them when I have used them. The cocaine should be a ten-per-cent. solution. Another means is boiling water cooled to 115° or 120° F. This I have used very liberally and have found no disadvantage from the comparatively high temperature. Pressure is another means which can be constantly and successfully applied by sponges, or by iodoform or other gauze.

But, after all, the chief reliance is to be placed on ligatures of catgut. They should not be chromicized, but are best prepared after the Jefferson method * by bichloride of palladium. The method of applying them is very important. While the larger arteries in the brain can be ligated in the usual way, the veins, which are very large, very full, and very fragile, are a much more troublesome source of hemorrhage, and require much more delicate manipulation. The greatest gentleness must be used during traction; and in tying, the traction on the two ends of the ligature must be exactly even or the vessel will be torn. In addition, the knot must be drawn only tightly enough to stop the hemorrhage, for if drawn too tightly it will easily cut through the fragile vessel. Weir has suggested in some cases the application of clamps to the vessels for twenty-four hours; very exceptionally they may be used, especially to the dura. Of course they must be included in the dressing.

It is occasionally necessary to trephine very near, or even over, one of the great sinuses of the brain, and in doing so it might easily be wounded. The sinus, however, may be avoided if due care be used. The trephine should be applied far enough from the sinus to be in a region of absolute safety. The opening can be enlarged later toward, or even over, the sinus with safety. In a recent case I recognized when I was near the lateral sinus by feeling the bony groove in which it is lodged by my finger introduced through the trephine opening. I could then separate the dura and sinus from the bone and could have trephined safely over the sinus, had it been necessary. In addition to this we may have to deal with a primary wound of a sinus itself. If the opening in the sinus is small, lateral suture of the sinus may be practised. If large and it cannot be closed by sutures, clamps may be used with advantage.

Pressure by a tampon of iodoform or other gauze has controlled it in a number of instances. In some cases the sinus has been tied by two ligatures, one in front and one behind, thus cutting off all possible hemorrhage, and the sinus excised as by von Bergmann and Küster. Barr has even suggested that in cases of thrombosis of the lateral sinus we may purposely open it after ligation, clean out the clot and remove this portion of the sinus. Care should be taken that no air enters the sinus lest sudden death should follow, as in Volkmann's case. In the same volume a series of nine experiments are reported on dogs by Genzmer, in which there was aspiration of air in six. (See also Senn's experiments.)

VII. *Treatment of the Brain.*—The first practical point to notice, after the dura is opened and hemorrhage controlled, is whether the brain *bulges* into the trephine opening. If it does so, it indicates a pathological increase of the intracranial pressure, a fact of the highest importance, since it will indicate either a tumor, abscess, blood clot, or dropsy of the ventricles. Bulging of the dura before opening it is, of course, equally significant.

Next, the *color* of the brain should be observed. A yellow tinge or lividity will probably indicate a tumor beneath the cortex. If the brain tissue be the seat of an old laceration its color will be altered, usually to a dirty yellowish brown. Next, the condition of the vessels and of the perivascular lymphatics must be observed, and particular notice should be taken whether there are yellow-white patches on them that may indicate any old mischief. Sometimes the membranes and convolutions will be densely matted into a yellowish cicatrix. In a number of cases I have seen *œdema of the membranes* sometimes so great as to obscure the sulci and convolutions to a marked extent. Precisely what is its significance, how far it is normal and how far pathological, I do not yet know. Nicking or snipping the membrane allows the serum to escape, and the sulci and convolutions to be recognized.

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* Annals of Surgery, January, 1898; Journal of Nervous and Mental Disease, 1894, xxi., p. 486.

Next, the *density* of the brain must be appreciated by the touch. If there be an abscess or dropsy of the ventricles the elastic tension will be increased, but, at least in dropsy, it will be very soft. If there be a large tumor the brain substance will be more resistant and dense than normal except in the case of soft sarcomata, etc. But it must be remembered that a small cerebral tumor at any distance beneath the cortex can scarcely be detected by this means. Should any hardness be detected, the brain substance must be incised and careful search instituted by the finger for the tumor or other pathological condition. If the finger be used it should be the little finger by preference, and great gentleness should be employed, or serious laceration of the brain substance will be produced. If abscess or dropsy be suspected the brain may be explored by a needle, knife, or grooved director. (For their comparative value, see page 414.) Wright, after trephining over the occipital lobe, even thrust a trocar through the tentorium down into the cerebellum and evacuated an abscess—a procedure I should not employ; trephining over the cerebellum itself would have been safer and better.

Next, the presence or absence of *pulsation* in the brain is to be noted. If a large tumor, abscess, or cyst exist it will be absent, but if a small tumor, cyst, or abscess be separated from the surface by any considerable layer of normal brain tissue, pulsation may be present. Altered brain tissue from old lacerations, etc., will generally pulsate.

In incising the brain, the knife should be carried down vertically into the corona radiata in such a manner as to avoid damage to the fibres coming from adjacent portions of the cortex, and the incision should run as nearly as possible parallel with the cerebral vessels which are "terminal."

Should the brain tissue be abnormal, the whole abnormal portion must be removed. It is important in doing this to remember that, while we should guard against producing any needless paralysis by removing healthy brain tissue, yet it is of prime importance that *all* of the diseased portion should be removed. If there be a cortical tumor (unless it is encapsulated or otherwise definitely limited), the necessity of removing a portion of adjacent and apparently healthy brain tissue, so as to get beyond the limits of infiltration, is of the greatest importance. If the tumor be subcortical, it can be sought for by the finger with great gentleness, and be removed either by a sharp spoon or other similar means, together with a suitable adjacent zone of healthy brain tissue. In all this removal of tissue adjacent to the tumor we can cut much more freely antero-posteriorly than vertically upward or downward. In the vertical direction we encroach far more quickly upon adjacent additional centres than we do in the antero-posterior direction.

VIII. *Recognition of the Brain Centre Sought for.*—In certain cases of Jacksonian epilepsy the object sought for is the removal of the centre whence the discharging lesion starts. In this case it will be necessary to recognize such centres by definite methods. In some cases the membranes and the convolutions are so matted together, and the brain substance so altered, that it will be impossible to recognize the sulci and the convolutions. But in these cases it is scarcely necessary to do so, inasmuch as all the damaged tissue should be removed, and, as before stated, we must even encroach to some degree upon apparently healthy brain tissue. In other cases, however, it is important and also possible to recognize the individual sulci and the convolutions, and to determine the precise part of the brain that is the seat of the discharging lesion, and therefore to be removed. The prolonged aniline lines on the undisturbed portion of the scalp, indicating the position of the fissure of Rolando, or the reapplication of the cyrtometer will here assist us very materially.

The determination of the brain centre by electricity has now been done in many cases most satisfactorily and without damage to the brain. The earliest four cases were those of Horsley, Keen, Deaver and Lloyd, and Nancrede. This is best accomplished by means of an ordinary faradic battery. In order more handily to use this means of diagnosis, I have had made a little rubber handle with two insulated points, the stems of which, being flexible, can be bent toward each other or separated as far as desired (Fig. 1023).

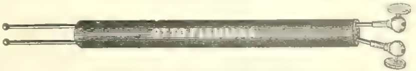

FIG. 1023.—The Author's Cerebral Electrode.

A very important point in this relation is stated by Horsley as the result of his experiments on animals. The cortex of the brain soon loses its excitability for electrical stimuli when bathed with antiseptic solutions. In any such case, therefore, it is desirable that the search for such cortical centres, by means of electrical stimuli, should be done *immediately* after the opening of the dura, and *before* any antiseptics have been applied. Usually none are now used. When once recognized, I have suggested, in order to prevent the need for repeated and possibly injurious applications of electricity, that the desired centre be marked by an aniline pencil or a nick. If the centre is to be removed the latter would do no harm.

IX. *Drainage.*—Drainage of the brain should be conducted on precisely the same principle as drainage for other parts of the body. Usually it may be entirely dispensed with. If it is used, however, it must be dispensed with as soon as possible. Generally I employ a gauze wick and remove it at the end of twenty-four hours. If not employed there is usually a considerable bulging of the flap during the first few days after the operation. This bulging, if it does not become too great, is not to be interfered with. If, however, it is more than a moderate bulging showing a considerable collection of wound fluids, a stitch may be cut and the flap gently and slightly opened. This will give egress to the retained fluids and the opening may be kept patent for twenty-four hours by a very small bit of gauze inserted for about half an inch. Primary union will follow the removal of this gauze.

In cases of abscess, gunshot wounds, hemorrhage, etc., or in cases in which there is danger of infection, the drainage must be more prolonged, and is best accomplished by rubber tubing. For the method of drainage in these conditions the reader is referred to other portions of this paper under the headings mentioned.

X. *Replacement of the Bone.*—Mr Macewen first showed the possibility of replacing the bone by mincing it up into small pieces and spreading it over the surface of the reunited dura. Clark, of Glasgow, was the first, I believe, to replace the entire trephine button with success. In the case of replacement the utmost care, however, must be given to the button from the moment it is removed to the time of its replacement. The instant that it is removed it should be placed in a cup containing a warm solution of bichloride (1 to 2,000), or warm salt solution, 0.7 per cent. This cup should be placed in a large basin in which lies a thermometer, and hot water should be poured into the outer basin from time to time to keep the temperature always between 105° and 100° F. It should be the duty of one assistant to attend to nothing else but to the water in this basin. All small fragments are also placed in this cup, and when the dura has been sutured the large discs of bone may be replaced, together with a suitable number of the small fragments bitten away by the rongeur forceps. If there be more than one large button, the triangular spur or spurs between the trephine holes should not be removed unless it is absolutely necessary in order to get more room, as they assist materially in keeping the buttons in their proper places. Should the membrane be removed, the bone cannot be thus replaced. In one case I successfully adopted the following expedient: I bored the centre-pin hole completely through the bone, and at the margin of the disc made another hole, also by the centre pin of the trephine. The two ends of a chromic catgut ligature were passed through these openings, and by needles these two ends were passed through the scalp and tied on the outside. The union to the scalp was complete, and the aperture in the skull was almost entirely closed by the callus. If the opening, after removing the disc of bone, has been enlarged by the rongeur forceps, the small fragments may be scattered closely together over the dura.

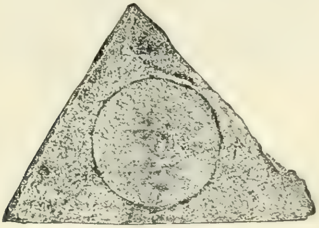
FIG. 1024.—Replaced Button of Bone. Inner surface.

XI. *Substitute for the Dura.*—In three cases in which the dura was necessarily removed, I have made an efficient new dura by stripping off a large piece of the pericranium, trimming it to fit the opening and then fixing it in place (with the osteogenetic surface outward) by a few sutures. Bone chips may then be sprinkled over the surface freely. These have united and formed a firm skull. Figs. 1024 and 1025, in the so far unique case of Burrell, show how complete the union may be after replacement of a trephine button. In case the bone is not replaced it will be well for the patient to wear a skull cap into which is sewed a metal plate somewhat larger than the opening, as a protection against blows and falls. If a drain tube has to be placed under the bone, a piece should be bitten out of its edge by the rongeur forceps to allow for the passage of the tube.

XII. *Closure and Later Treatment of the Wound.*—Hemorrhage having been checked, the dura sutured as described on page 408, and the bone replaced with provision for drainage if deemed useful, the scalp should now be replaced and secured with sutures. An abundant dressing is to be applied and retained in place by suitable bandages. The dressing will most probably be saturated with blood and serum at the end of a few hours. If so, the wound should be redressed. At the end of twenty-four hours the wound should always be redressed, when, as already directed, the drainage is to be removed, or slight drainage provided by a bit of gauze if the wound fluids necessitate the slight opening of the scalp wound. The next dressing should not be done until the wound fluids have saturated the dressing to its margin. By the fifth day, it is my rule then to redress the wound for the purpose of removing any stitches that may be no longer needed. In operations on the brain in which the bulging above referred to has produced some tension on the stitches, it is best not to remove them too early; but usually all of them may be taken out by the seventh or eighth day, and some of them by the fifth. If by the fifth day primary union has been secured, a mere protective dressing may be applied. In a few days this may be dispensed with, but the patient, on account of his shaven head, should wear a skull cap, or some other means of protection against taking cold.

XIII. *After-Treatment.*—If the case be not one with active inflammation, and if union by first intention has been secured, the patient should be well within a week or ten days, without an elevation of temperature much above 100° F., and possibly not even up to that point. The bowels and the diet should receive the ordinary care.

One thing is of the greatest moment after such operations: no excitement, study, business, household cares, or mental worry should be permitted for several weeks, or, better, for several months, after the operation.

XIV. *Secondary Operations.*—A number of these have been done. Mr. Horsley has referred to some in his paper. Nancrede has reported one, and Stokes another by Franks, and I have done several. The membranes will commonly be found to be quite adherent to each other and to the brain tissue, and if it be necessary to dissect them off the latter, it is almost inevitable that some portion of the outer layer of the cortex will be removed along with them, producing paresis in the centres thus encroached upon; hence it should be done with the greatest gentleness and care. After removal of a motor centre there is, of course, entire paralysis of the part supplied by this centre; and the pressure caused by the blood clot which accumulates and the later cell proliferation is apt to cause widespread paralysis, amounting even to a hemiplegia. After some weeks this invariably disappears to a greater or lesser extent, leaving, however, the affected muscles, it may be, somewhat paretic. The cicatricial tissue between the brain and the bone very likely will be quite vascular, and, possibly, traversed by large veins. Should the dura not have been opened at the first operation, it will still be adherent to the brain itself, and probably covered by a layer of granulation and cicatricial tissue, which must be dealt with according to the needs of each case.

XV. *The Limits of Operative Interference with the Brain.*—Over twenty years ago I perforated the squamous bone and passed a probe between the dura and along the petrous bone to a depth of two inches, in a search for an abscess. I found no pus, but the search did neither good nor harm. Weir has proposed, in a case of aural disease with subsequent cerebral mischief, in a similar manner to lift the dura to a point corresponding to the roof of the tympanum; and if need be, in suppurative meningitis of the middle fossa, to open the dura and drain the fossa. He has well likened the petrous bone to the appendix vermiformis, as a focus of inflammation followed by suppurative processes in the dura or arachnoid, either local or general. It is followed, therefore, by external pachymeningitis and extra-dural abscess, internal suppurative meningitis, or cerebral or cerebellar abscess, all of which he suggests may be similarly relieved by operation. The same excellent surgeon has shown (and I have verified the procedures partly on the living subject and partly on the cadaver) that the cerebellum can be lifted sufficiently to obtain a view as far as to the foramen magnum; the same foramen can be reached by the finger on the inside, and from the outside by both the eye and the finger; the longitudinal and lateral sinuses

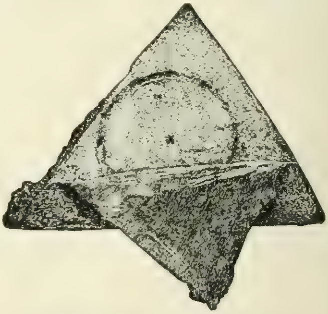
FIG. 1025.—Outer Surface of the Same Button.

can be safely uncovered and separated from the skull; and the frontal lobe can be lifted far enough to expose the anterior clinoid processes.

Horsley has reached an exostosis of the orbit almost at the optic foramen, and has stated that the tumor of the auditory nerve, reported to the Neurological Society of London by Dr. Sharkey, could have been removed by incision of the tentorium and ligature of the lateral sinus.

Other cases, referred to in this paper and elsewhere, show that the sinuses may be tied and exsected; a very large part of the surface of the skull, up to even the size of the palm, or even more, may be taken out; large tumors, up to over nine ounces, may be successfully removed, and considerable areas of brain tissue may be cut away with safety and advantage.

A large portion of the base of the brain can be explored by the finger, the eye, and the probe or director, and the substance of the brain can be punctured almost with impunity, repeatedly and to a depth of two inches and more, without leaving any injurious trace behind.

I have shown also that the lateral ventricles can be safely reached. In many cases, especially since my paper was published, the ventricles have been tapped with success. Even a wound involving them is not necessarily fatal.

MENINGOCELE, ENCEPHALOCELE, AND HYDRENCEPHALOCELE.—For the more detailed account of symptoms and physical signs of these diseases, see the article entitled *Brain: Cephalocele* in the present volume. In this article I shall consider them only briefly and from the surgical point of view.

Meningocele, encephalocele, and hydrencephalocele are allied malformations of the brain which are fortunately not common.

1. **MENINGOCELE** consists in the protrusion of the membranes of the brain through an aperture in the bones of the skull, the sac formed by the membranes being distended to a greater or lesser extent by fluid which is extra-cerebral.

2. **ENCEPHALOCELE** consists in the protrusion of a portion of the brain itself, as well as of the membranes, usually with a smaller amount of fluid within them, the fluid again being external to the brain substance.

3. **HYDRENCEPHALOCELE** consists in the protrusion of the brain substance itself as well as of the membranes, but in this case the interior of the mass communicates directly with the ventricles, and is often filled with a large amount of the ventricular fluid, so large in some cases that the layer of brain substance enclosing the fluid is reduced to a very thin film.

All three forms of the disease arise in intra-uterine life, and are therefore congenital. The most frequent is unfortunately the gravest form—viz., hydrencephalocele—and the least frequent is meningocele. As a rule, they are apt to be fatal early in life. Their commonest situation is, first, in the median line, especially in the occipital region; next, in the fronto-nasal region, and lastly, at the sides of the skull or about the base. Of 93 cases collected by Houel, 68 were occipital, 16 fronto-nasal, and 9 at the sides and base.

Diagnosis.—They have been mistaken for abscesses, nævi, sebaceous cysts, etc. The following points of diagnosis will generally enable the surgeon to reach a proper conclusion:

All of them are congenital, commonly median, and especially occipital in position. Meningocele is usually cystic in its feel, is translucent, fluctuates, rarely pulsates, is more or less pedunculated, generally becomes tense in forced expiration and is easily reducible. Encephalocele is usually small, is opaque, does not fluctuate, pulsates distinctly, has a wide base, becomes more tense in forced expiration, and symptoms of pressure are produced on attempting to reduce it. Hydrencephalocele is generally large, is lobulated, is partially translucent, fluctuates distinctly, pulsates but rarely, is usually pedunculated, is made only slightly more tense in forced expiration, and is not reducible.

All three forms are apt to be combined with other deformities, and paralysis often accompanies hydrencephalocele.

Treatment.—As a rule, hydrencephalocele is not amenable to treatment. The child fortunately dies early. The other two forms hold out more hope, especially if they are small. Sometimes an encephalocele by retrograde development may be changed into a meningocele, and occasionally by gradual concentric ossification, resembling that of the fontanelles, the bony aperture is lessened and may even close. The intracranial communication with the interior of the sac may be narrowed and finally obliterated, thus partially or completely effecting a spontaneous cure. Until the late improvements in cerebral surgery, nothing was usually recommended in the way of treatment, certainly not unless there was danger of rupture. A number of successful cases of excision, however, have been recently reported, and, unless the size of the tumor or the condition of the patient forbid, this should be attempted, of course with all the antiseptic care bestowed on other brain operations. Enough scalp should be preserved to make sufficient flaps to close the opening. If operation be felt inadvisable, electrolysis may be used as a substitute. Pressure and the injection of Morton's fluid (iodine, gr. x.; potassium iodide, gr. xxx.; glycerin, ℥ i.) may be tried, but with little prospect of benefit.

INTRACRANIAL ABSCESS.—*Causes.*—Nearly one-half of the cases of abscess of the brain arise from a suppurative process in the ear. Occasionally they arise from an acute inflammation of the ear; but much more frequently they are a sequel of chronic ear disease. Occasionally they will follow even a few weeks after suppuration, but they are far more commonly a sequel years after scarlet fever, or some other exanthem, has set up a discharge from the ear. The situation of such abscesses is most frequently in the temporo-sphenoidal lobe.

Barr, in 76 cases of cerebral abscess following disease of the ear, found 55 in the temporo-sphenoidal lobe, 13 in the cerebellum, 4 in both the cerebrum and cerebellum, 2 in the pons, and 1 in the peduncle. When situated in the temporo-sphenoidal lobe they are not necessarily directly in contact with the petrous bone, but may be separated from it by even an inch of apparently healthy brain tissue. They reach the cerebellum usually by the track of the lateral sinus, in which very often thrombosis occurs. The mastoid cells are very frequently, but not always, involved. The discharge is almost always fetid.

The next most frequent cause is injury. Frequently this injury has not been very severe, but even a small scalp wound, if it becomes septic, may involve the bone, the veins, or the lymphatics, and then the encephalon. Moreover, if recovery apparently takes place, the patient is by no means safe, as a number of instances are on record in which several weeks or months, and in some instances even a number of years, have elapsed between the infliction of the injury and the development of the abscess. A most remarkable case of late development of abscess, and of its correct localization, is given by Mr. Damer Harrisson in the *British Medical Journal*, April 21, 1888. A boy, aged *fifteen*, had received a severe blow on the *left* side of the head when *four or five years of age*. No severe symptoms followed the wound, but nine or ten years later, for about a year before his admission, twitching and flexion of the wrist, biceps, and deltoid had been observed. Eight days before his admission he had received a blow on the *right* side of the head from a pair of tongs. Three days after this accident a convulsion on the *right* side of the body suddenly set in, beginning in the arm, then spreading to the face and leg, and followed by paralysis of the *right* side of the body. Repeated convulsions followed his admission. Mr. Harrisson trephined the boy, not at the site of the last, but at the cicatrix of the *first*, injury, and eventually evacuated four drachms of fetid pus, and the boy made an uninterrupted recovery. Macewen (*loc. cit.*) reports a remarkable case in which an acute abscess developed later in the periphery of an old encysted abscess. After evacuating several ounces of pus, the old abscess appeared "like a tennis-ball floating in a sea of pus." Wagner (*loc. cit.*) gives two cases of abscess, arising seven and nine years respectively after falls, without any external wound; and Souques reports one of abscess arising eleven years after a fracture of the skull.

If the injury is followed by meningitis, this will usually develop within three or four days; but should it result in abscess rather than in meningitis, it will not usually form earlier than at the end of the first week. The situation of an abscess after a blow or fall is almost invariably under the site of the injury, but, as is shown by Macewen's earliest case, Harrisson's, and others, the location of the abscess must be fixed by considering not only the site of the injury, but the focal symptoms as shown by cerebral localization—*e.g.*, in Macewen's case the abscess was in Broca's lobe, but the cicatrix was on the forehead.

Still another occasional cause is localized meningitis. Of this, perhaps the most instructive case yet recorded is that found in the very able paper of Mr. A. E. Barker, in which the pus, accumulating undoubtedly between the island of Reil and the operculum, produced upward pressure on the motor centres for the face and arm. Complete recovery followed the operation.

Metastatic abscess occurs not infrequently in the brain as a result of various conditions, even in distant organs, such as gangrene of the lung, fetid bronchitis, and bronchiectasis. Tuberculous abscesses also are sometimes seen, but in both these cases the abscesses are usually multiple, and hold out but little hope for any successful surgical treatment. Wernicke and Hahn and Fränkel have reported two cases of tuberculous abscess which were single.

Symptoms.—The symptoms of cerebral abscess may be arranged in three categories: 1, those due to the suppurative process itself; 2, symptoms arising from general pressure; 3, focal symptoms.

1. Among the symptoms arising from the suppurative process itself, usually the most important is fever, and it is especially noteworthy that in intracranial abscess the temperature is either *normal* or *subnormal* most of the time, even when the gravest general symptoms exist. The temperature, however, does sometimes rise, especially toward the end, and is often attended by delirium, but will generally subside quickly, only to rise again after an interval if the patient survive long enough. Von Bergmann and others state, however, that the local cranial temperature in abscess will rise. If, therefore, symptoms of serious intracranial pressure exist, if the general temperature is normal or subnormal, while the local temperature shows a rise and the pulse is slow, the first thought of the surgeon should be to seek for evidence of abscess of the brain. A chill not uncommonly occurs, but may be absent. Of course there will be loss of appetite, vomiting, general malaise, etc. Somerville has stated that when pus is present in the brain, the chlorides in the urine will be below the norm and the phosphates above; but I know of no confirmatory examinations of this important assertion.

2. Among the pressure symptoms, headache holds an important place. It is almost invariably present, and not uncommonly of an extreme and severe type, so that the patient will constantly moan; and if he be sufficiently intelligent, this will be the one thing of which he will complain. It is apt to become worse, and when the temperature occasionally rises it is often located distinctly at the focus of the lesion, but sometimes is general. It does not, therefore, always serve as a guide to the situation of the abscess. The pulse is almost always slow, and may even fall to thirty or forty in the minute. Respiration is often of the Cheyne-Stokes type. The mental condition is very soon impaired, and gradually, as the pressure increases, becomes worse and worse until the patient may become comatose. Not seldom the bowels and bladder will be evacuated involuntarily. Convulsions of an epileptic type often occur, but not usually when the abscess is situated in the temporo-sphenoidal lobe. Sometimes convulsions will be the very first acute symptom. Muscular twitchings may occur, and if so, their occurrence will often point to the cortical centre involved. Sensation is not usually much impaired.

The presence or absence of choked disc does not seem to be pathognomonic, as it is sometimes present and sometimes absent. When present, even if bilateral, it is almost always more marked on the side of the lesion, though this is sometimes reversed. Not uncommonly there will be ptosis, and sometimes paralysis of the entire third nerve, while the sixth may escape; though sometimes the reverse is the case. The pupil of the same side is generally dilated, and more or less immobile. Almost all the symptoms of pressure vary from time to time, and the patient's general condition fluctuates in a remarkable degree, sometimes simulating recovery, soon to relapse again into a worse state than before. Theoretically, there should probably be deafness of the opposite ear if the first or second temporal convolution is involved; but this symptom is very uncertain.

When the abscess is situated in the cerebellum, the diagnosis is apt to be very obscure. Occipital headache and rigidity of the neck muscles often exist. Inco-ordination of movement, and especially an unsteady, drunken gait, indicates pressure upon the middle lobe. Vomiting and vertigo are frequent and persistent. If these symptoms exist with tenderness on pressure and pain on percussion over the cerebellum, they may point definitely to the cerebellum. Optic neuritis is not frequent in cerebellar abscess. But here, above all other localities, the remark of von Bergmann eminently applies: "The technique of the evacuation of brain abscess no longer deters us from operating. All progress in treatment must depend chiefly upon diagnosis." It is, therefore, especially important that all cases of brain abscess should be observed and reported with the minutest and most exact detail, especially if there is any suspicion of the cerebellum being involved, in order that we may learn how to make a more exact diagnosis.

At present the condition of the reflexes is not known with sufficient accuracy to be of much value in diagnosis, though they are probably increased on the side of the lesion. Their study is therefore all the more important, not only in abscess, but in all other cranial lesions.

3. The symptoms by which the locality of an abscess may be inferred are chiefly those which are so admirably described in general by Dr. M. Allen Starr, in his article on *Brain Diseases: Diagnosis of Local Lesions*, in the present volume. I need, therefore, only briefly recall a few leading facts. The left temporo-sphenoidal lobe being adjacent to Broca's convolution, a very common result of abscess in this lobe would be motor aphasia. If the abscess is of such size as to press upon the inferior centres of the motor region, paralysis or paresis of the opposite side of the face would probably be first induced, followed by paralysis of the arm, and occasionally even by complete hemiplegia of the opposite side. If the ear disease has implicated the seventh nerve in its passage from the petrous bone, there will be, of course, palsy of the same side of the face. Sometimes there will be a distinct squint from paralysis of the sixth nerve. Especially are all localizing symptoms valuable in those cases, which are not altogether rare, in which there is a suppurative discharge from *both* ears.

Mr. Barker has suggested that at the operation the mastoid foramen, through which passes a small vein to the lateral sinus, should be laid bare and an examination for pus be made. Should pus be found exuding from this foramen, it would certainly be a most valuable sign; but thus far I do not know that its examination has proved to be of positive value. The foramen (Figs. 1026 and 1027, *i*) lies one and one-fourth inches behind, and about one-fourth inch below, the external meatus, at the base of the mastoid process.

Should the abscess exist in the frontal lobe, as is sometimes the case from nasal disease, but little information can be derived from localizing symptoms, this lobe being a "latent" region. In the occipital lobe the same is true, unless the cuneus is involved, when hemianopsia on the same side of each retina would certainly follow. Should the angular or supramarginal gyrus be involved in the lesion, the state of the pupil may possibly give valuable information. In the *American Journal of the Medical Sciences* for October, 1888, pp. 349 and 355, Dr. Oliver has described a species of monocular Argyll-Robertson pupil, which seems to promise to be of value in lesions of this region.

The temperature of the two sides of the head should always be carefully taken, and in doing so it should be remembered that the left side is normally hotter than the right (Gray and Seguin, *Arch. of Med.*, December, 1879). Should abnormal variation of the local temperature be observed, it would be a valuable indication, but one that as yet is not sufficient to localize an abscess with absolute certainty.

Percussion and pressure on the head are also valuable, but alone are not to be relied on absolutely. Taken with other symptoms, they may assist materially in the localization of an abscess. Hulke records an instance of a tender spot above the ear in a case of abscess in the cerebellum; and another of a tender spot over the occiput with an abscess in the temporo-sphenoidal lobe. Pain on *percussion*, but *not spontaneously complained of*, in the opinion of Ferrier, is of greater value than mere tenderness on pressure. Pressure and percussion are of value, in many cases, in diagnosticating cerebellar abscess from cerebral. Should the abscess, as occasionally happens, be extra-dural, its locality would almost certainly be indicated by œdema of the overlying scalp. This, therefore, should always be looked for.

Differential Diagnosis.—First, *meningitis:* This is often a very difficult differential diagnosis. In meningitis there will usually be delirium, delusions, photophobia, contraction of the pupils, convulsive facial twitchings, high general temperature, and marked rigidity of the neck muscles, all developing rapidly after an injury or from disease of the ear, or in a strumous patient.

Secondly, *mastoid disease*, following purulent otitis media, sometimes gives rise to serious cerebral disturbance. Trephining the mastoid—which in nearly all cases of cerebral abscess, at least from ear disease, will precede the opening of the skull—will, in general, quickly differentiate this from intracranial abscess. As a rule, the mastoid region will be swollen, œdematous, and painful; in other words, will present the usual evidences of mastoid disease. For the diagnosis from extra-dural abscess arising from mastoid disease, see page 415.

Thirdly, *thrombosis of the lateral sinuses and pyæmia* would most likely involve the internal jugular vein, into which, most probably, the thrombus would extend. It would be hard, cord-like, and painful, and the veins of the face would almost certainly be turgid and swollen. Besides this, very probably, there would be general symptoms of pyæmia, such as involvement of the joints, lungs, liver, etc. The temperature also would never, as in abscess, be near or below the normal, but of the pyæmic or "pump-handle" type. There would almost certainly be rigors, profuse sweating, and great general prostration, without such marked dulling of the intellect as exists in abscess.

Fourthly, *tumor*. While in most cases the diagnosis between abscess and tumor can be pretty clearly made, yet, in not a few cases, the diagnosis is difficult and sometimes impossible. Usually the development of a tumor is very slow, and is attended with distinct focal symptoms from the time when its existence is first manifested. While the development of abscess may be deferred in its outbreak, yet once started, it usually runs a much more rapid course than a tumor. Moreover, abscess has usually some evident cause, as either injury, aural or nasal disease, etc. Tumor sometimes develops as a result of injury, but more commonly without. In tumor the optic neuritis is almost always double, and usually more intense than in the case of abscess. In abscess, also, choked disc is much rarer, and if present, it is not rarely unilateral instead of bilateral, and may be on the side opposite to the abscess rather than on the same side (Ferrier and Horsley's, Barker and Gowers' cases).

While tumor sometimes exists in the temporo-sphenoidal lobe or in the cerebellum, yet abscess is far more common in these situations. In other parts of the brain tumor is far more common than abscess. If syphilis exist as a cause, it is far more likely to give rise to tumor than to abscess. The temperature is not apt to rise in either case. Rapid and sharp fluctuations in the general condition of the patient would be more suggestive of abscess than of tumor; slow fluctuations are more common in tumor. Emaciation without sufficient cause sometimes attends abscess.

Surgical Treatment.—The almost uniform mortality that attends abscess of the brain, if not relieved, renders any means that holds out a reasonable prospect of relief a necessity. Very many such cases of abscess have been operated upon successfully by trephining, even so long ago as when Dupuytren and others boldly punctured the brain. So early as August, 1849, Detmold even punctured the ventricle itself and evacuated an abscess, and Dr. George R. Morehouse, of Philadelphia, informs me that he did the same during the Civil War. All this was done with boldness, it is true, but we must also add that in the majority of cases it was rather the result of happy chance than of scientific precision.

The operation has entered upon an entirely new career since the establishment of the doctrines of cerebral localization. Abscesses in the brain, in the last few years, have been frequently and accurately localized, and successfully operated upon, by a large number of surgeons.

When abscess from ear disease is suspected, the mastoid should in most cases first be trephined and carefully washed out. Should this operation not give relief, then we must proceed further and trephine the skull. But before this is done, the ear and the mastoid should be most carefully cleansed with a borated solution and filled with powdered boric acid, in order to prevent any possible infection of the brain. The head should be shaved, certainly over a *large* area, or better, entirely, and the scalp cleaned and disinfected in accordance with the method already described.

The question as to where the trephining shall be done is an important point. As already related, even in case of abscesses arising from injury, the scar is not always over the point at which the abscess exists. It must be located by cerebral localization quite as much as by the site of the external lesions. Moreover, tenderness on pressure is not always a reliable indication of the site at which the trephining should be done, though tenderness on percussion is a more reliable sign.

In order to attack an abscess in the temporo-sphenoidal lobe two points are advocated. Mr. Caird, who operated on Greenfield's case, applied the centre pin of the trephine one inch and a quarter behind the external angular process, and nearly one inch above the zygoma. This seems to me a very undesirable point, because it would generally strike the middle meningeal artery at, or just below, the antero-inferior angle of the parietal bone, where the artery not infrequently passes through a bony canal, and might give rise to hemorrhage which at least would be troublesome.

A point three-fourths of an inch in front of the meatus and an inch and a half above Reid's "base line" was the spot I selected in a case of trephining for supposed cerebral abscess, for reasons there given. It is better than Mr. Caird's, I think, as it avoids the artery and even its posterior branch, and gives access to the temporo-sphenoidal lobe at about its middle; but the danger of wounding the middle cerebral artery, if the brain is incised or punctured, is possibly even a more serious objection. In certain other cases in which the symptoms seem clearly to point to such a location, this point might, however, be selected with advantage.

In the majority of cases, however, I should agree with Mr. Barker that the best place for trephining is one inch and a quarter behind the external auditory meatus, and the same distance above Reid's "base line" (Figs. 1026, *c*, and 1027). This is just above and behind the junction of the petrous with the remaining portions of the temporal bone. Even in children the distance above Reid's "base line" should be the same, I find, for at a lower point the upper border of the petrous bone would greatly and suddenly thicken the inferior edge of the button of bone and might give some trouble in its removal. A director thrust downward, forward, and inward in the direction of the opposite ala of the nose would pass through the axis of the temporo-sphenoidal lobe, and be almost certain to strike an abscess of any size. Should it fail to do so, punctures may be made in various other allied directions, in order to reach possible small abscesses. As pointed out later, this same trephine opening can also be utilized for tapping the lateral ventricles, if necessary.

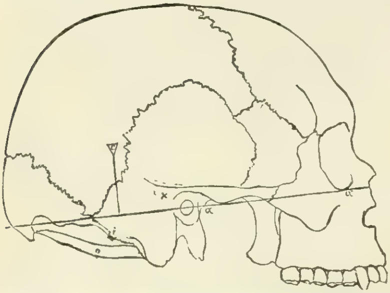

FIG. 1026.—From a Photograph of a Dissection of the Skull Before Exposing the Brain. *a*, *a*, Reid's "base line," running from the lower border of the orbit through the centre of the auditory meatus; *c*, the exact point at which the pin of the trephine was applied to open the cerebral abscess, just behind the squamosal suture; *x*, the point at which the mastoid antrum was opened; *i*, the foramen for the mastoid vein; *o*, on the point below the inferior curved line at which the cerebellum should be explored if abscess arises in it. (Barker.)

In the report of the operation above alluded to, I have shown that repeated punctures may be made with a grooved director or hypodermic needle without any serious damage to the brain substance. I have there stated at some length my reasons for preferring the grooved director to either the knife or needle for *exploration* alone. A needle sucks up healthy brain tissue, even when the suction power does not exceed seven to ten minims, and the danger of wounding the vessel is not an imaginary one. With the director we feel much more safe, and will, therefore, be proportionally bolder and more thorough in our explorations. Such boldness and thoroughness, combined with safety, will often result in success, when timidity from possible danger would result in failure. In a recent case I punctured the frontal lobe four times with a director, and to the depth of two and one-half inches, without any evil symptoms as a result. Rivington, in 1881, was, I believe, the first to use the director boldly in this manner. He thrust it two inches into the brain. The remarkable paper of Spitzka shows how freely we may puncture the brain without evil result. In many cases no trace of the puncture could be found, and where it existed there was only usually a trace of blood. Even the filthiest mud was injected into animals' brains, with but little damage as a rule.

For *incision*, however, as distinguished from *exploration*, the *knife* is certainly to be preferred. As soon, therefore, as the abscess cavity is reached the knife should be used, and then a pair of hæmostatic forceps be introduced, closed, and drawn out expanded to a reasonable degree, in order to afford free vent for the pus. Should the wall of the abscess cavity be lined with granulation tissue, it should be removed by the sharp spoon or otherwise, just as in case of an abscess in other parts of the body, care being taken not to encroach on any important neighboring centre or vessel. The abscess cavity may now be very gently washed out with normal salt solution, and a rubber drainage tube then be inserted. This should be passed through a good-sized buttonhole opening in the flap, and secured to the scalp by a long silk thread tied in a bow knot. The bone should not be replaced. If the first trephine opening does not afford good drainage a second should always be made in the proper place. An ample dressing should then be applied. The drainage tube should be kept in place, but gradually shortened until the discharge has diminished to such an extent that it is safe to remove it. The silk thread may be untied, secured to the tube, and retied at will. Even with the greatest care it will happen every now and then that the wound, after apparent healing, will have to be reopened to give vent to a reaccumulation of pus, as in a number of cases already reported. Thus McCutcheon trephined his patient five times for as many different objects: (1) after the accident; (2) for compression; (3) for epilepsy; (4) for atrocious headaches; (5) for necrosed bone; each operation being followed by benefit, and the final one by recovery. Fenger and Lee operated three times, Rivington operated four times, and Schede operated five times. All of these cases recovered. In Westmoreland's case the blow was received in 1879, and repeated attacks of suppuration occurred in 1881, 1883, and 1886. In each case reopening the wound and redraining resulted in recovery.

Of course, if a fistula be discovered, even a small one, as in the case reported by Truckenbrodt, and operated on by Schede, the trephine opening would be made at the site of the fistula rather than at any of the points above described, and would lead to the abscess. Weir has suggested the injection of an aniline solution to discover the route and extent of the sinus.

If the abscess is in the cerebellum the proper place to trephine is well below the superior curved line, so as to avoid the lateral sinus, the centre pin being placed midway between the tip of the mastoid process and the inion. A three-quarter-inch trephine or the chisel or a gouge should be used. It must be remembered that the skull is quite thin and easily penetrated at this point. The opening can be enlarged later if necessary.

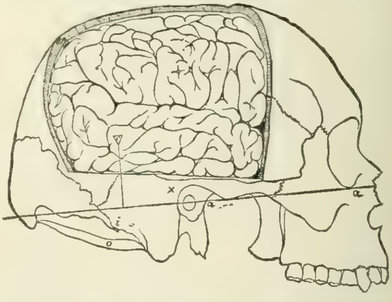

FIG. 1027.—Photographed from the Same Skull, with the Brain Exposed *in situ*. The lettering is the same as in Fig. 1026. The point at which the opening was made in the central cortex (*c*) is observed to lie on the posterior part of the second temporo-sphenoidal convolution. (Barker.)

The flap in the dura should have its base upward. Of course, the occipital artery will have to be ligated. As pointed out by Weir, "with the use of a spatula to lift it up slightly, the cerebellum can, if necessary, be viewed with an electric light nearly to the foramen magnum." With a grooved director or other appropriate means, the cerebellum can now be punctured and the abscess evacuated in a favorable position for drainage. Even should the abscess be upon the opposite side of the cerebellum, it would be easy, as I have shown, to reach it obliquely through such an opening. In making any puncture, however, care should be taken not to injure the superior vermiform process. A drainage tube should be used and the abscess treated as before described.

If an abscess exists in any other place than in the temporo-sphenoidal lobe or in the cerebellum, the trephining should be done immediately over the site, as determined by cerebral localization, and the cavity treated as above described.

Should no abscess be found at the first trephine opening, and there be a possibility of its existence at another point, there is no objection to a second trephine opening, and even a third, should the necessity arise. The danger from an additional trephining is so slight, and the danger from abscess, if it exist, so great, that we should seek for it at a second or even a third point, if not found at the first. It is, however, scarcely necessary to add that this additional trephining should not be done without good and sufficient reasons. In such cases, when the abscess is found to be encysted and encapsulated by a thick membrane, the membrane should, of course, be removed, as was done by Bergmann.

Extra-Dural Abscesses.—Besides the abscesses in the substance of the brain, another variety exists that it is very important to recognize; that is, an abscess between the dura and the bones of the skull. These almost always arise from ear disease by involvement of the bone and subsequent pachymeningitis externa followed by suppuration. The pus may accumulate in an abscess, or may be diffused between the dura and the skull.

Symptoms and Diagnosis.—They cannot be distinguished from cerebral abscesses proper, or from leptomeningitis or thrombosis of the lateral sinus, by the eye symptoms or headache, but other means may enable us to do so. The temperature, in marked contrast to cerebral abscess, will rise to 102°–104° F. The pain in extra-dural abscess is usually fixed either above or behind the ear, and is increased by percussion or by pressure. The mastoid, of course, will be involved, but the tenderness on pressure or percussion will extend both farther back and higher up than the mastoid. Usually there will be œdema of the overlying scalp. If the mastoid has already been opened and no improvement has followed, and no marked symptoms of the other cerebral diseases mentioned above be present—such as the pronounced cerebral irritative lesions of leptomeningitis, the localizing or focal symptoms and low temperature of cerebral abscess, or those of thrombosis of the internal jugular, and other signs of pyæmia in plugging of the lateral sinus—we should suspect extra-dural abscess. Pressure symptoms are rarely seen in extra-dural abscess, especially if it arise from aural trouble. If evidence exist of caries of the bone, extra-dural abscess should be suspected, and especially if the pus well up through such a sinus and show any pulsation communicated from the brain. Not seldom a sequestrum or carious bone will be found.

Treatment.—The ordinary operation for trephining the mastoid will usually have been done for the earlier symptoms. If not, it should be done at once, and further operative interference be carried out, if so indicated. If the operation be limited to opening of the mastoid, and this does not speedily bring relief, the skull itself should be opened either by the trephine or by the rongeur forceps. The probe or escaping pus will indicate to us any fistula, and this must be followed up till the carious or necrosed bone is discovered and the dura laid bare. This last can usually easily be recognized by its texture, its relation to the bone, and its pulsation. Should the lateral sinus be exposed, care must be taken not to wound it. Should a thrombus exist, it must be treated as indicated under that heading later. That recovery may take place after thrombosis of the sinus and without interfering with it, is shown by a case of Hoffmann. The abscess cavity having been reached, it should be cleaned out, the granulations from its walls removed, and free drainage provided, all carious or necrosed bone having, of course, been first removed. Unless such efficient operative measures be taken, the case is almost sure to prove fatal. Hoffmann, whose paper (*loc. cit.*) is the best study of the subject I have found, gives a ghastly table of 102 fatal cases in which the diagnosis was established by a post-mortem examination, and its impressive lesson is but reinforced by the 10 additional cases diagnosticated during life. Four of these were observed by others, of which 3 recovered after operation; 6 are reported by himself, of which 5 recovered after operation, one dying six weeks later from bronchitis. No other commentary as to the absolute necessity for an operation can be needed. The causes of death were mostly meningitis, cerebral abscess, and pyæmia, with, and probably from, thrombosis of the lateral sinus.

Pyæmia and Thrombosis of the Cerebral Sinuses.—Under the title *Ear: Intracranial Complications*, etc., in Volume III. of the present work, Dr. Orne Green considers this matter very much more fully, especially from the point of view of the otologist. A few words, however, ought to be said about it from the view of the general surgeon. This is all the more true, because nearly all the cases until within the last few years have passed unrecognized and unoperated on, while the results of operation have been extraordinarily good.

In a table which I published in Ashhurst's "International Encyclopædia of Surgery," (supplementary volume), I collected 84 cases, of which 56 recovered—66.7 per cent. Since that time a large number of cases have been reported, but no later complete tabulation to my knowledge has been made. I have no doubt that a considerably larger percentage of recoveries would be shown in the later cases.

The cause of the thrombus may be infected fractures, erysipelas, decayed teeth, etc., but by far the larger proportion of the cases arise from chronic otitis media. The thrombus, being an infected one, gives rise to a pyæmia with all of its ordinary symptoms. The infected clot softens and suppurates. Very frequently it extends into the jugular vein, whence fragments of it will eventually reach the lungs unless the progress of the disease is stayed. While the thrombus takes place in the vast majority of cases in the sigmoid portion of the lateral sinus (the curved portion of the sinus occupying the groove in the mastoid portion of the temporal bone), yet there are a fair number of instances reported in which the superior longitudinal sinus, the cavernous and other cerebral sinuses have been involved. The symptoms will be detailed fully in Dr. Green's article.

The only treatment to be considered for a moment is the surgical, and this must be prompt and thorough in order to be effective. The mastoid operation, if not already done, should immediately be carried out. If the internal jugular is involved, this should be exposed in the neck and tied below the thrombus, in order to prevent infection of the lungs. Ordinarily this thrombus can be readily recognized by touch, but sometimes, as in one of my own cases, the vein is so completely destroyed by suppuration that it is difficult to recognize it. Next, the sigmoid sinus should be exposed and deliberately opened. It should be cleaned as far as the clot extends; if need be, even to the torcular Herophili. If serious hemorrhage occurs, it can readily be controlled by plugging with strips of iodoform gauze. The vein and the sinus should be washed out both from above and from below. The petrosal and the cavernous sinuses cannot be reached by surgical operation.

Up to the present time, the symptoms of thrombosis of the superior longitudinal sinus have not been sufficiently clear to enable the surgeon to make a positive diagnosis of the location of the disease. Whenever we can do this, a similar operation to that on the sigmoid sinus should be done.

Intracranial Tumors.—The *causes* of intracranial growths are various, but in the majority of cases the cause can scarcely be ascertained. Injury occasionally plays an important rôle, but much more frequently they arise without any apparent local cause. The statistics of Hale White, and Bernhart, quoted by Seguin and Weir, give a sufficient number of cases from which to draw a reasonably correct conclusion. They number 580, and are as follows:

	Number.	Per cent.
Nature of tumor not stated	133	22.9
Tuberculous tumors	137	23.0
Gliomata	76	13.0
Sarcomata (including cysto-sarcoma)	75	13.0
Hydatids, cysticerci, and echinococci	30	5.0
Cysts	27	4.6
Carcinomata	24	4.0
Gummata	21	3.6
Glio-sarcomata	14	2.2
Myxomata (including myxo-sarcomata)	12	2.0
Osteomata	6	1.0+
Neuromata	4	−1.0
Psammomata	4	−1.0
Papillomata	4	−1.0
Fibromata	3	
Cholesteatomata	2	
Lipomata	2	
Erectile or vascular tumors	2	
Dermoid cysts	2	
Enchondromata	1	
Lymphomata	1	
Cases	580	

This shows that tuberculosis is nearly twice as common as any other one known cause. Tuberculous tumors are most frequent in early life, three-fourths of them occurring before twenty, and one-half before ten, years of age (Gowers). The various forms of malignant tumors exceed in number even those which are of a tuberculous nature. They are most common from twenty to forty. Other varieties, excepting hydatids and cysts, furnish each but a small number. The small percentage of syphilitic gummata is rather surprising. Dr. Gowers states that of 637 intracranial tumors the distribution was as follows: Cerebral hemispheres (excluding the central ganglia), 297; cerebellum, 179; pons, 59; central ganglia, 48; medulla, 31; corpora quadrigemina, 13; crura cerebri, 10. Starr, in a valuable paper on 300 cases of intracranial tumors in children, found 96 in the cerebellum.

The *Symptoms* have been so carefully studied and so fully treated by Dr. Mary Putnam-Jacobi, in the present volume of this HANDBOOK (article on *Brain, Tumors of*), and by Dr. M. Allen Starr, in his article on *Brain: Diagnosis of Local Lesions* (see p. 282), that it would be but a repetition here for me to consider them. Three points, however, ought to be more fully noticed, viz., disturbance of language, eye symptoms, and local temperatures.

A most important paper in connection with disturbance of language is that by Dr. M. Allen Starr. Words in ordinary use have a complex mental substratum, made up of a number of mental pictures. These are, first, memory of the sound of a word as spoken; if this be lost we have "word deafness." Second, memory of the appearance of a word as printed or written, if this be lost we have "word blindness." Third, memory of the muscular movements made in writing a word; if this be lost the result is "agraphia," or inability to write. Fourth, memory of the muscular movements made in pronouncing a word; if this be lost, although the vocal apparatus is perfect, it is known as "motor aphasia." Fifth, the word-hearing and word-uttering processes may be perfect, and the patient can understand what is said to him, and can pronounce words well, but the connection between the word-hearing and the word-uttering processes is broken, and the patient misplaces words or uses one word for another—for instance, calling the "four of spades" the "five of telephone." This is known as "paraphasia," or the aphasia of conduction of Wernicke. The lesion in these cases usually involves the island of Reil, and severs the fibres beneath it, the great association tract joining the temporal and frontal lobes with one another. Sixth, the mind may not recognize the use, odor, color, taste, etc., of any object presented to it. This general symptom is termed "apraxia." It has, of necessity, as many varieties as there are avenues by which the mind may be reached; for instance, by sight, smell, taste, hearing (not only hearing for language, but also for music), either of which may be lost separately, thus producing "mind blindness," "mind deafness," etc. The patient, however, though unable to recognize any object when *seen*, may be able to do so when *felt*. These symptoms (according to Starr) are found only when the lesion is in the left hemisphere in a right-handed person, and in the right hemisphere in a left-handed person. Hence, in examining an aphasic thoroughly, Starr states that it is necessary to test, first, the power to recall the spoken or written name of an object, seen, heard, handled, tasted, or smelled. Second, the power to understand speech, and also music. Third, the power to understand printed or written words. Fourth, the power to speak voluntarily. Does he talk clearly? Does he mispronounce words or talk jargon? Fifth, the power to repeat words when dictated. Sixth, the power to read aloud. Does he understand what he reads? Seventh, the power to write voluntarily. Can he read what he has written? Eighth, the power to write at dictation. Ninth, the power to copy. Tenth, the power to recognize the use of objects seen, felt, heard, tasted, or smelled. One illustration, and only one, so far as I know, exists of the diagnosis of a lesion by the existence of "mind blindness," and this was followed by a brilliant and successful treatment. This is recorded by Macewen, and is briefly quoted on page 425 of this article.

When it is remembered that the second, the third, the fourth, and the sixth nerves, in their entirety, are solely intended for innervation and specializing function of the organ of vision, it will be readily understood how important this apparatus becomes as an index of intracranial disturbance.

The methods may be briefly given in a series of short captions, as follows:

1. Always, if possible, get *central vision* in each eye separately, not only for form but for color, as this practically gives the physiological power of the most highly evolutionized fibres of each retina. To do this, cards of known sizes of types or symbols, and graded areas of definite colors, such as green, red, rose, blue, and yellow, should be placed at certain distances in good light, and the results compared with the normal standards for such distances. Should the patient be unable to designate types, symbols, or colors, then keys, coins, etc., of the same size as certain test letters can be held at the related distances, or less if necessary, and attempts made for similar selection among duplicates held in the lap.

2. *Power and range of accommodation* should be tried separately and combinedly for the smallest type visible, with or without helping lenses, at the nearest, furthest, and best points possible. Retinoscopy may be useful in quite a number of cases. Tonic and clonic spasm must be sought for.

3. *Visual fields* must be most carefully studied in reference to comparative sizes and areas for white, yellow, blue, red, and green; blind spots and points of feeble color saturation must also be diligently sought for and noted.

4. More complete study of *central color perception* should now be made with graded intensities of Holmgren's wools, and the results should be recorded upon suitable blanks.

5. The *pupils* should be examined and re-examined separately and in associated action, until definite answers can be given as to their comparative sizes and shapes.

6. Careful attention must be paid to monocular and binocular *action of the irides* to light stimulus thrown from all parts of the visual field; to associated action with the ciliary muscles, as in accommodative efforts; and to the combined and associated action with the ciliary muscles and internal recti muscles, as in convergence, and these tests must be repeated over and over until unequivocal results are obtained. Spasmodic action of the irides must be carefully looked for.

7. *Extra-ocular muscle balance*, when the organs are in a state of rest, should be obtained as correctly as possible.

8. Combined and disassociated *action of the attached extra-ocular muscles* in convergence, conjugate deviation, extreme separate and combined excursions in all directions, must be gone over with special study of the varying degrees of change from the slightest loss of innervation up to total paralysis. Search for clonic and tonic spasms should also be carefully made.

9. Combined and associated *action of the muscular apparatus of the ocular appendages* should now follow, in reference both to paretic and to spasmodic changes.

10. *Sensibility of the entire ocular superficies*, both to touch and pain, should be studied.

11. In cases in which a difference of temperatures is suspected, *comparative surface thermometry* should be made, although it is really best not to omit it in any instance.

12. Accurate *ophthalmoscopic study* of the media and the fundus of each eye should be repeatedly made, until adequate data as to the comparative condition of the two organs are correctly obtained.

Having thus obtained this grouping of ocular conditions in association with the history and concomitant symptoms, determinations can often be made of sufficient accuracy to point out at least not only the probable character of the lesion, but even its possible situation. Negative signs may oftentimes prove themselves of great value in the diagnosis of the position of the supposed growth; and no case can be said to be complete and ready for surgical procedure until all the ocular changes have been properly and carefully studied.

For the purposes of help in differential diagnosis the few following general observations may be of use:

Optic neuritis is very usual in some stage of intracranial tumor, and indicates more rapid progress of the growth. It is of no definite value in the diagnosis of the position, the character, and the size of the mass.

If the so-called monocular type be met with in such cases, the neoplasm is most probably situated in the opposite hemisphere; and should the neuritis be double (*which is most probably always the case*), it is almost certain that the side of the lesser optic nerve swelling is the one in which to look for the growth. The occurrence of this symptom is less frequent in abscess, and may be more ordinarily found upon the same side as that of the lesion than in tumor. It seldom occurs, if at all, in cortical lesions with irritative symptoms.

Primary optic-nerve atrophy with or without retinal change, as shown by the ophthalmoscope, is generally found in connection with basilar disease or trunkal inflammation, from trauma, new growths, general dyscrasia, and the introduction of toxic agents into the system. In epilepsy it is seldom decidedly marked, being usually found in its incipient form, and seemingly dependent upon the number and severity of the seizures. It is not apt to occur in abscess, except in those rare cases of the encysted and slowly growing varieties.

Weakening of any single muscle or any group of muscles generally indicates either pressure from a coarse lesion, external to any portion of the related outgoing fibres, or true infiltration of pathogenic material into the neural meshes themselves. Unassociated with other symptoms it is of little value in questions of the position of the lesion, and must be used in conjunction with other data to be of any determining use. Being, however, more of a fixed quantity than muscle irritation, it is of greater importance in such instances than the latter, as it better shows the probable position of the lesion. Localized spasm in itself is probably more apt to be caused by lesions in the motor zones and in the centres devoted to the action of the involved group or groups of muscles. It thus often offers itself of special diagnostic value in the localization of the initial point of the epileptic spasm.

In acute and subacute meningitis, irritative symptoms of both motor and sensory varieties appear, whereas in the chronic form degenerative changes are more prone to occur.

Hemianopsia is of paramount importance, more so than aphasia and agraphia. Each variety, carefully considered in conjunction with ophthalmoscopic study, experiments with pupillary responses, and other motor and sensory disturbances, can hardly fail to serve as most important data for indicating the probable situation of the lesion.

It must be remembered, however, that each ocular symptom in itself is not etiologically self-answerable. Careful study must be made of all the conditions, so that, by the process of exclusion, adequate data can be obtained upon which to base answers as to the character, the type, and the situation of the supposed intracranial lesion.

Surface Temperature of the Head.—Mills and Lloyd, in Pepper's "System of Medicine," vol. v., p. 1036, have given the record of four cases of tumor of the cerebrum and one of the cerebellum. Seguin and Weir (*loc. cit.*) have recorded the temperatures in their case, and I have done the same in the case of tumor in my first paper already referred to. The general conclusion seems to be that the average temperature of the whole head is elevated somewhat above the normal, and that the elevation of temperature is usually greatest at the station nearest to the site of the growth. But a much larger number of observations must be made in order to reach a definite conclusion as to this symptom; therefore, every case of supposed tumor, and, in fact, every other lesion in the skull, should have the surface temperatures carefully noted both before and after the operation, if any be done. In the second case in my paper the temperature certainly seemed to be elevated by the irritation of the lesion present. The elevation immediately disappeared after the operation, coincidently with the cessation of the epileptic attacks. In the third case in which the fits were relieved, but not cured, the temperature did not fall. Our surface thermometers also are as yet much lacking in accuracy, as they are used in practice.

Diagnosis.—While in many cases the diagnosis is sufficiently clear, in others we are, of necessity, in the greatest doubt, until the operation, it may be, reveals the correctness or the incorrectness of our conclusions. Hence, as already quoted with approval from von Bergmann, the great necessity of a correct diagnosis on the part of the neurologist, so that the surgeon may be sure that his attempt to remove a supposed tumor will not cause chagrin to both by finding none. This has occurred in numerous instances.

In the careful and elaborate paper of Seguin and Weir, already referred to, it is pointed out that the diagnosis before operation must be worked out in five lines of inquiry. (1) The existence of tumor; (2) its exact location; (3) whether it is cortical or subcortical; (4) whether solitary or multiple; (5) its nature; to which I would add (6) if possible, its size.

1. *Diagnosis of the Existence of a Tumor.*—When the symptoms referred to by Dr. Jacobi, in her article, are present—such, *e.g.*, as headache, cerebral vomiting, gradually developing stupor, convulsions either general or localized, paralysis in varying degrees, choked disc, sometimes hemianopsia, slow pulse, probable localized rise of temperature with aphasia and apraxia, and in some cases with but little anæsthesia—it is almost certain that we have a tumor to deal with. The most difficult diagnosis is often between tumor and abscess, and for their differential diagnosis I must refer the reader to the article on *Brain: Abscess of*, on p. 218.

2. *Diagnosis of the Location of the Tumor.*—This must be done chiefly by the localizing symptoms. In certain parts of the brain a tumor may exist and give rise to no localizing symptoms, but only to general headache, choked disc, convulsions, etc. This is more particularly in the anterior portion of the frontal lobes, in the temporo-sphenoidal lobes, especially on the right side, and in parts of the parietal and occipital lobes. But gradually these "latent zones" are being narrowed progressively to smaller and smaller portions of the cerebrum. It is not too much to hope that eventually there may be *no* "latent zones." The reader must refer to that portion

of this article which treats of Topography of the Brain, and to Dr. Jacobi's and Dr. Starr's papers in the present volume, for the details of the methods of localization, whether in the motor or in the sensory zones. One point must be regarded in following the history of a case. If a tumor increase in size, centres *adjacent to the first one involved* will also be affected; hence a succession of additional spasms and of pareses will develop in different parts of the body, and they are very important to study. The first limited spasm or paresis Seguin has proposed to call the "signal symptom"—a happy name for an important symptom in diagnosis. Rapidly produced blindness, as pointed out by Zenner and others, is usually due to tumors (especially in the cerebellum) which obstruct the veins of Galen or the straight sinus, and so produce internal (ventricular) hydrocephalus and pressure on the optic tracts, followed by choked disc and hemorrhages.

3. *The Diagnosis of the Depth at which a Tumor Lies, i.e., whether Cortical or Subcortical.*—Seguin, in the article already quoted, concludes that a tumor of the cortex cannot be distinguished from a subcortical tumor by the character of the convulsions, or by the presence or absence of localized headache, or by the cranial temperature. But tenderness on *percussion* rather than on pressure may very possibly be of some service. In this as in the question of local temperatures, it must be urged that more exact and detailed clinical histories may hereafter give us the means of making such a diagnosis. How near one may come to removing a tumor and yet miss it, is well shown in a case of Sands, in which he recognized unusual resistance in two punctures by the needle, yet did not remove the growth, which was found at the autopsy just below the surface. Surgery had not then reached its present boldness and success.

4. *Is the Tumor Solitary or Multiple?*—If solitary it may be successfully attacked by operation, but if multiple such an attempt would be clearly inadvisable in most cases, unless the multiple tumors are grouped within a limited area. If the tumor is single, the localizing symptoms will probably point to one area alone, if the tumor be small; or if large, several areas may be involved, but these areas will be adjacent to the primary one. If, however, localizing symptoms give two or more centres, far apart, without any intervening centres being involved, then the multiplicity of the growth is probable.

5. *The Diagnosis of the Nature of the Tumor.*—In some cases this may be made with fair approach to accuracy. For example, if the patient has cancer, tuberculosis, or syphilis in other organs, and shows characteristic symptoms of intracranial tumor, it will most likely be of the same type as the disease in the other part of the body. Beyond these three classes of tumor I do not think it possible to make other than a guess at its nature.

Hale White and von Bergmann are both opposed to operation in case the nature of the tumor is probably syphilitic. I quite agree with Seguin, however, that, provided thorough antisyphilitic treatment has been ineffectual, including the American method of the administration of large and increasing doses of iodides, if possible up to half an ounce a day, the probable gummatous character of the tumor or a syphilitic disease of the bones or membranes is not a bar to operation. Once a gumma has become organized and permanently developed, and has resisted vigorous specific treatment for six weeks, it should be attacked precisely as any other tumor would be dealt with, surgically, unless contraindicated by special symptoms, such as multiplicity, etc.

6. *The Size of the Tumor.*—This in a few cases can be probably diagnosticated. The diagnosis of a small tumor will be based upon its involving a restricted area of representation in the brain, as shown by the limited portion of the body involved; by the non-progressive involvement of neighboring centres; and by the absence of marked pressure symptoms. A large tumor will involve a large number of neighboring centres and would show marked pressure symptoms. Until the parts are exposed by operation, however, it is impossible to make any accurate diagnosis of the size of a tumor. It is probable, however, that a few of them will be so large as to prohibit surgical interference, before the general symptoms will be so grave as to make such interference quite inadvisable.

Surgical Treatment of Intracranial Tumors.—I have already referred to the historical case of Bennett and Godlee, which was the first really to arouse the attention of the surgical world to the possible diagnostication and removal of a brain tumor, of which there were no external local symptoms. I have also referred to some later cases which have been operated upon. The number of intracranial tumors operated upon has now reached such proportions (*vide infra*) that we can assume it as conceded that in all suitable cases operation should be at least attempted.

As to operative technique I have already considered the various steps under that head. The only point necessary to be insisted upon here is, that in cases of tumor which are not encapsulated, it is important that not only the entire tumor shall be removed, but also the zone of apparently healthy but probably infiltrated brain tissue in its immediate vicinity, so that we may be sure, so far as it is possible, that we have removed the entire neoplasm. In doing so the surgeon must remember that he can excise with greater impunity a larger area in the antero-posterior direction than in the vertical, for reasons already given.

Prognosis.—If the tumor is malignant, its return is only a question of time in the majority of cases. In tuberculous and syphilitic tumors the prognosis is, of course, a a much more favorable one; while in cases of benign growths, such as fibroma, recurrence is not to be expected.

The prognosis as to death or recovery from such operation cannot be made in any individual case, for up to the time of the operation we cannot be certain of the size and the relations of such tumor, nor of the surgical complications that may arise during its removal.

The *percentage of recoveries* in cases of operation on intracranial tumors has been, for a new operation, unexpectedly large. Of course, in any individual case, it will depend largely on the size, position, complications, etc.

When the first edition of the REFERENCE HANDBOOK was published, I could gather only 17 cases of tumor which had been operated on, of which 3 were in the cerebellum and all 3 died.

In 1898 von Bergmann published the most recent statistics, which cover 273 operations for intracranial tumors of all kinds, of which 169 (61.9 per cent.) recovered and 104 (38.1 per cent.) died. One hundred and fifty-seven were exploratory or palliative operations, of which 82 (53.5 per cent.) recovered and 75 (46.5 per cent.) died. The chief reason for the fatality in exploratory or palliative operations has been either too extensive exploration in search of the tumor or for its removal, or that many of the cases were inoperable from the size or location of the growth and only relief from intracranial pressure was sought. If no tumor is found after cautious search by the knife, grooved director, and the gentlest use of the little finger, or if, being found, it is not removable, the operation should be terminated at once, especially if there is much bulging, indicating a large tumor. In fact, in cases of great increase in the intracranial pressure, until I have determined the fact that the tumor can be removed, I am very cautious about making a large opening in the dura, since the pressure will force out a large amount of brain substance which cannot possibly be replaced without extensive laceration, which invites fungus cerebri. Of fourteen cases in which trephining was done for the relief of increased intracranial pressure, all recovered.

Another important cause for the high mortality of the whole series has been the delay in operating. Physicians, who almost always see these cases first, postpone consulting the surgeon for an unreasonably long time in the vain hope of improvement. It cannot be too strongly insisted upon that tumors of the brain should be treated precisely like tumors in other parts of the body, by removal at the earliest practicable moment. In fact, in the brain the reasons for early operation are even more cogent than elsewhere: its soft tissues are more easily injured; it cannot escape from pressure as do the soft parts, since the bony case in which it lies prevents this; and the growth of the tumor within the skull is insidious and not easily perceived, as it is when accessible to touch and sight. Progressive growth can be inferred only from progressive symptoms. As soon, therefore, as drugs have had a fair trial an operation should immediately be done, if the tumor can be located with reasonable certainty and if there is a fair prospect of success by operation. The limit of the "fair trial" Horsley places, and I think rightly, at six weeks. After that, time is wasted and life imperilled by longer waiting, since time only allows of increase in the size of the tumor with wider infiltration of brain tissue and the wider destruction by pressure, and the operative difficulties and dangers rapidly increase with each week or month of delay.

In the case of irremovable tumors, the opening in the skull should not be closed by replacing the bone. This partial operation will often be an immense comfort, and I have had the same experience that Horsley has had —namely, that the patient found so much relief from one operation that he requested a second.

Operations upon cerebellar tumors—by reason of their proximity to the fourth ventricle, the tubercula quadrigemina, and the pons with their important and vital centres—are more hazardous than those performed in any other less vital regions of the brain. Out of 23 cases, 15 died.

EPILEPSY.—From a surgical point of view cases of epilepsy may be sharply divided into the traumatic and the non-traumatic varieties. The cases arising from traumatism can again be subdivided into (1) those in which the scar, old depression, etc., arising from injury, lies over well-recognized centres, motor or otherwise, and (2) those in which the evidences of injury lie over the so-called "latent zones" in the brain.

In those cases in which the lesion lies over well-known centres, and the epileptic fits affect only the muscles corresponding to the motor centres (monospasm or hemispasm), there can be no question at present as to the propriety of surgical interference, and the excision of the epileptogenous centre so involved. In cases in which the injury lies over a portion of the "latent zones," I believe that here also it is often proper to operate.

It is true, time has cooled our earliest enthusiasm, but epilepsy is such a terrible disease that I find most parents are of my own opinion, viz., that no risk, even of death, still less of the probability of failure, is to be weighed against the possibility of benefit or cure. The danger of death is not very great, the number of failures is large, the number of cases benefited is considerable, the number of cures is limited but encouraging. If we could operate early, before the "epileptic habit" is formed, the number of cures would be much greater.

In these traumatic cases it is always possible that the scalp may be the site of irritation, and should there at least be no evidence of depression of the skull, it would always be wise, therefore, to *excise the scar* first of all, especially if it be tender, or if pressure upon it produces pain or an epileptic fit, or if the epileptic aura starts from the scar. Even should none of these symptoms be present, and if the bone be not fractured, I should deem it right first to excise the scar and then to wait in order to see whether this would cut short the epileptic seizures. Thus Briggs reports five such cases and Mears one in which such a happy result followed mere excision of the scars. I also have had two cases in which the attacks have not returned for several years after merely excising the scar. In one case the immunity has reached nine years. Any other source of peripheral irritation must also be eliminated, as has long since been observed. Briggs relates a case in point in the same paper, in which a girl had both a depressed cranial fracture and necrosis of the tibia. He wisely operated on the tibia first to eliminate this as a source of irritation, and the fits had not recurred when the case was reported five years later, thus disproving their origin from the fracture of the skull, which was *prima facie* the most probable cause. It must be remembered also that *any* operation is apt to cause a cessation of the fits for some time; hence, before deciding that the epilepsy has been cured by removal of the scar or other source of irritation, at least two or three years of immunity should elapse. Should excision of the scar not cure the patient, or should there be a depression of the skull, with fits corresponding in their distribution to the motor centre or centres over which the scar lies, the patient should be trephined. The operator may find a splintering of the inner table. Sometimes a cyst will have been developed under the site of the injury. Sometimes, as a result of laceration of the brain tissue at the time of the injury, a brain scar will be found. The dura also will have been ruptured in some cases, and a scar will be found in it; or mere eburnation of the bones, as a result of osteitis from the traumatism, may be the only lesion. The skull having been trephined and the dura opened, the damaged brain tissue should be removed; and if there be a scar or thickening of the dura, the dura itself should be removed. In removing the damaged brain tissue, care must be taken to see that it is *all* removed, even to the extent of trenching upon apparently healthy brain tissue, and the directions heretofore given that freer excision may be made in the antero-posterior direction than in the vertical (for reasons already mentioned) must be remembered. The bone should not be replaced in a large piece, if by its shape, or for any other reason, it would cause pressure on the brain. It may sometimes be replaced to advantage after dividing it into small pieces by the chisel or rongeur forceps.

In those cases in which the lesion lies over the "latent zones," the same rule as that given above would apply to the excision of the cutaneous scar. Should this not effect a cure, then it would be proper to operate. What should be done would depend upon what was found to exist in the brain, and any damaged brain tissue or cyst should be excised as already advised. Occasionally, after accidents, primary trephining will have been done, yet epilepsy will develop at a longer or shorter time after healing. In such cases, no matter where the scar is situated, it is sometimes wise to raise the flap over the site of the primary trephining and round off the edges of the bone, and to excise any scar in the dura or in the brain which may have resulted from the primary traumatism, or from any operation done at that time. Occasionally some benefit will follow, but generally the result will only be a temporary cessation of the attacks.

Non-Traumatic Epilepsy.—First, of the Jacksonian type. So far as our limited experience goes, it seems probable that in cases of distinct Jacksonian epilepsy it is proper to operate, and to excise the centre corresponding to that portion of the body which is involved. The experience of Horsley and Macewen, as well as quite a number of other operators, at present would seem to show that such operations at least do no harm, and in not a few cases they have resulted in apparent recovery both from the epilepsy and from the operation. It is a matter of some importance also that if we operate at all, it shall be as early as possible, before the "epileptic habit" has been established. But both in this and in the non-Jacksonian type, *it is of the utmost importance that the fits shall have been always observed by a competent, and, if possible, a trained observer.* I have had brought to me for operation a large number of cases of alleged Jacksonian epilepsy, and others of ordinary epileptic type, in which the fits were said to be limited and uniform in the point of beginning. These statements have been in some cases the result of the patient's knowledge, but more commonly of that of members of the family only. It is very evident that persons not trained to exact observation, and especially those persons whose affections are involved, and whose first motive would be to aid the patient rather than to observe the fit, are, as a rule, incompetent observers. Frequently, after placing such persons under observation in hospital, I have found that the fits had not been at all correctly described. Therefore it cannot be too strongly insisted upon that accurate observations shall be made the foundation of knowledge before we proceed to excise any brain centre. In making these observations, not only should the observer note all the phenomena in detail, and especially the muscles involved—particularly the muscle or muscles *first* involved (Seguin's "signal symptom")—and the "march" of the fit (that is, the progressive involvement of one muscle or set of muscles after another), but the dynamometer should be used as soon as possible after the fit to determine whether the muscles involved in the fit be paretic.

Such operations have been seriously objected to on the ground of subsequent paralysis. This seems to me not to be a valid objection. To exchange epilepsy for paralysis would, I think, be a choice at which few patients would hesitate. It must also be remembered that the excision of a centre for an ordinary group of muscles, though it be followed by paralysis which may even be complete, has resulted eventually in so great a restoration of power as to convert the paralysis into only moderate paresis, probably through the compensative action of the centre on the opposite side. Thus, in the third case related in my first paper already referred to, in which excision of the wrist centre was done, the patient was entirely paralyzed from May 30, 1888, till early in July. Motion began to return at this time, and when I last saw him, in the middle of September, 1888, he had so far regained control of his hand as to be able to play baseball. The fits, however, had persisted, though changed in type, there being now but few severe convulsions, and only a moderate number of attacks of *petit mal*. In another case in which I excised the thumb centre the hand and arm became paralyzed to the elbow. This rapidly disappeared, and in a few weeks the patient could again sew perfectly well and the dynamometer showed no difference in the muscular power of the two thumbs.

As to operative procedure in these cases, it is important, first of all, to obtain a view of the brain sufficiently large for the operator to be able to recognize the convolutions. Once the convolutions are exposed, no antiseptic solution should be allowed to touch them until the centre sought for shall have been well defined by the battery. Hot water, however, may be used to check the bleeding. As soon as the brain is uncovered the faradic current should be employed by means of my double electrode (Fig. 1023, page 409).

The remainder of the operative procedure is as described in the section on the technique.

Secondly, in cases of general or "essential" epilepsy experience has shown that it is better to refrain from operation as a rule.

INJURIES OF THE HEAD.—*Contusion.*—In any case of serious contusion, the patient should at once be put to bed on light diet, and the bowels and general hygiene carefully looked to. The patient should then be closely watched, and, if any serious symptoms arise indicating intracranial mischief, a semicircular flap of the scalp should be raised and the bone inspected. If a fracture of the bone be discovered and the symptoms are at all serious, showing that inflammation of the meninges or of the brain substance has set in, or is impending, exploratory trephining must be done at once, and the dura be opened. Even if no fracture exists, if the symptoms are those of encephalitis, trephining should be done. It is possible, in such a case, either that a piece of the inner table has been separated, with or without external fracture, or that the dura has been ruptured or the brain lacerated, and that inflammation with exudation has begun. Once inflammation with its attending proliferation has set in, it is essential that a means of escape for the exudate be provided for, or for the escape of pus if the inflammation shall have proceeded so far. In other words, we should treat contusions followed by serious symptoms of mischief in precisely the same manner that we would treat them in any other part of the body, always remembering that in the brain it is impossible for any exudate or hemorrhage to find its way to the surface without surgical assistance, by reason of the bony case in which it is retained. Trephining of the skull, therefore, is equivalent only to incision through the soft parts down to the seat of injury in any other part of the body. In many cases of very severe contusion, it would be proper immediately to make a horseshoe flap in order to determine the question of fracture. The swelling of the scalp is often so thick and so dense that in some cases it is extremely difficult to ascertain whether a fracture exists or not without such an incision. It is all-important to know this fact, and especially if there be depression or not, so that the proper treatment shall be adopted. *Preventive trephining*, in many of these cases, is not only justifiable but demanded. A simple incision through the scalp is of itself unattended with danger in these days of antiseptic surgery. It may be objected that if a simple fracture exists, by such an incision we convert it into a compound one; but the position taken by Roberts in 1885 is certainly the correct one, that such an incision, with modern surgical methods, adds nothing to the danger, and is the only method by which we can make an absolutely certain diagnosis in any serious case, and so enable us to pursue a course of treatment which will diminish or avoid the danger.

Should there be motor paralysis without any decided loss of sensation, there is almost certainly a lesion of the cortex; but, as Ferrier has pointed out, if sensation is impaired to any extent, there is probably a lesion of the sensory tracts of the internal capsule, or of the centres to which they are distributed.

Even after recovery from a severe contusion of the head, the patient should be carefully watched for some months, as in not a few instances abscesses, cysts, or epilepsy has developed after a long time. One case in which I trephined, a month after an exploratory incision of the scalp alone had been made, was most instructive as to the intracranial effects of a very slight extracranial traumatism. In enlarging the trephine opening, I found that the dura suddenly became remarkably adherent to the bone. Inspection showed me that the area of adhesion was precisely under the flap of the first operation. This had been simply the raising of a flap of scalp, had been conducted with the utmost antiseptic care, and had healed without incident in a few days; yet the simple lifting of this flap had been felt instantly within the cranium, and exhibited itself by the strong adhesion between the dura and the bone. A severe contusion, therefore, it can easily be understood, even without fracture of the bone, might set up such inflammation as would ultimately lead to suppuration, to the formation of a cyst or a tumor, or to such organic changes as would be followed by epilepsy. Williams has reported an unusual case in which a blow on the forehead produced an abscess which discharged through the nose.

Compression of the Brain.—In 1885, in a paper read before the American Surgical Association, Roberts insisted that the complexus of symptoms passing under the title of "compression of the brain" was due not so much to compression as to brain laceration and inflammation. In cases of encephalic hemorrhage, we certainly have an example of compression. Apart from this cause, and probably from tumor and from effusion, in both of which, however, inflammation has a large share, I certainly would agree with the position taken by him. A blow which is followed by symptoms of compression, when it is sufficiently serious to produce violence to the membranes, or laceration of the brain tissues, is, as a rule, one which has been followed by inflammation; and it is this inflammation with its exudate and swelling that causes the mischief. We are apt to think of increased intracranial pressure as a result to be looked for only from tumor, abscess, or effusion into the ventricles. But it is certainly reasonable to believe that mere inflammation of the cranial contents will be attended by swelling as in other tissues, and that thereby the intracranial pressure will be increased.

An experiment by Felizet is full of instruction. He filled a skull with melted paraffin, and after this had cooled, he let the skull fall from a moderate height to the floor. The calvarium was then removed. No fracture existed, but the surface of the paraffin was flattened at the point corresponding to the blow. The skull had been momentarily depressed, and had returned again to its former shape by its elastic resiliency. Undoubtedly the same occurs in the brain, and no such momentary changes of form from violence, even though followed by a restoration of the organ to its original place, can have been produced without more or less laceration of the brain tissue. What is to be feared is that inflammation will take place, and that the products of inflammation will produce symptoms of pressure. Hence, in such cases, I would trephine for the same reasons as are given under the last heading, if similar symptoms arise.

Scalp Wounds and Injuries of the Head.—In every case of scalp wound, the head should be shaved over a *large* area, and scrubbed with a nail brush and soap and water, followed by an application of ether, and then of a sublimate solution. The scalp should, of course, by this process be thoroughly cleansed from all dirt and foreign substances, and if need be the edges of the wound should be trimmed in order entirely to get rid of the dust and dirt. The wound may now, and not until now, be examined by a probe and the finger, both of which must be entirely aseptic. Should the injury be limited to the scalp and the periosteum, after providing for drainage, the wound should be closed and dressed antiseptically. But should the skull be fractured, it should be treated as described below. In wounds which produce a crushing or sloughing of the scalp, the late Dr. William Hunt called my attention to the fact that the depressed scar resulting from loss of scalp tissue only, not seldom may be mistaken for an old depressed fracture of the skull—an error he had known to be made by more than one good surgeon.

Simple Fracture of the Skull without Depression.—This is often exceedingly difficult to diagnosticate. One of my patients, a bright, intelligent fellow, experimented on his own head the morning after a fall of nine feet, by tapping on his head on the injured side. He elicited a "cracked-pot" sound which did not exist on the uninjured side. It is possible that this may be sometimes of great value in diagnosticating simple fracture without depression. If the fracture be simple and without depression, and without cerebral symptoms, it should be treated expectantly, but the moment that there are any symptoms of encephalitis the trephine should be used for the reasons previously stated. Two most instructive cases of such trephining are reported by Heusner.

Simple Fracture with Depression.—In simple fracture with depression I should certainly advise immediate preventive trephining, even if there be no sign of encephalic mischief present, although I am quite aware that many conservative surgeons are opposed to such radical treatment. As already stated, the conversion of a simple fracture into a compound one is at present attended with no serious risk. It must be remembered that any violence sufficient to break a bone and to depress it will unquestionably have produced some laceration of the brain substance, and possibly of the dura. In addition to this, as the inner table is so much more easily fractured than the outer, occasionally a fragment may have been detached and driven into the brain. The immediate dangers arising from such a fragment of bone and laceration of the cerebral tissues and membranes are those of serious inflammation, and if the products of inflammation are confined within the skull, without possibility of escape by drainage, the danger is a serious one. Even should the patient recover, as is undoubtedly often the case, the numerous instances of epilepsy arising from irritation of a scar, from a cyst, or from secondary degeneration are so great, and the danger of trephining so small, that but little choice would seem to exist.

Compound Fractures of the Skull.—The rule in such cases should be always to explore by a large incision in the scalp. Should there be no depression, no strong probability of separation of the inner table, or of serious laceration of the brain, or of hemorrhage, the wound should be most scrupulously disinfected, and, after careful antiseptic dressing, the expectant plan should be pursued. Should the fracture be a mere linear fissure, after careful disinfection, if the fissure be at all impregnated with hair, dirt, etc., the soiled edges should be carefully chiselled away so as to make sure that we have cleaned them of all infective material; for it is in the probable infection more than in the mere fissured fracture (apart from the violence of the accident) that the danger of encephalic mischief lies. In doing this only the outer table need be cut away. An antiseptic dressing should then be applied.

But if depression exists, and there are symptoms which lead us to believe that serious injury to the brain, or fracture of the inner table, or hemorrhage is present, preventive trephining should be done at once. It goes without saying that a large area of the scalp should be shaved and most rigidly disinfected in all these cases.

Mr. Mayo Robson has reported an excellent illustration of the value of comparatively *early* trephining in such cases. A man received a blow on the left side of the head directly over the arm centre, the scalp showing a small lacerated wound. The right arm was paralyzed, this condition being attributed by the surgeon who first saw him only to bruising. Later rhythmic epileptiform spasms began in this hand, followed by facial paresis, œdema of the left optic disc, and exaggerated reflexes on the right side. Exploration showed a depressed fracture, and trephining saved his life. The twitchings disappeared in six days after the operation. Even had he recovered without operation he would probably have suffered from a Jacksonian epilepsy.

In a case of extensive compound fracture of the occiput, so early as 1810, Hutchison boldly anticipated modern surgery with the happiest results. The patient had fallen thirty feet and fractured the occiput, the fracture extending into the foramen magnum, as proved at the operation. He was trephined at once, and, to the embarrassment of the surgeon, the dura bulged beyond the outer surface of the bone, and by its elasticity showed that there was an extravasation of blood beneath it. The next day this was incised, the blood evacuated, and, after a tedious illness from a suppuration that would now happily be conspicuous by its absence, the patient recovered.

In *Punctured Wounds of the Brain*, which are of course always compound fractures of the most dangerous character, the rule should be *absolute* to trephine at once, whether there be brain symptoms or not. The almost certain danger of septic inflammation, and the need both for immediate provision for drainage and for antiseptic cleansing of the wound, render immediate trephining imperative, just as incision, cleansing, and drainage of a similar wound in the soft tissues is the rule. No better illustration could be given than that of a case reported by Ball in which a man was struck on the left temple with a pen-knife. The wound was not considered serious enough to warrant his admission to the hospital where he first applied. Ten days later aphasia, word blindness, and word deafness set in, without paralysis. Five days later he was trephined. The knife blade had penetrated the dura and wounded the brain. A clot was removed and drainage provided for. The next day his aphasia recurred, but disappeared after the blocked drainage tube was made pervious and further clots removed. An excellent recovery followed.

Wagner states that in 81 cases of complicated various fractures of the skull *freshly treated* as above advocated, the death rate was only 1.23 per cent.; whereas in 12 such, treated *secondarily*, the mortality was 33.5 per cent. No better commentary could be made.

Gunshot Wounds.—The experience of the last fifteen years in cerebral surgery has revolutionized the treatment of gunshot wounds of the brain. The application of antiseptic methods to the treatment of brain injuries, the consequent boldness with which we operate on the brain and its membranes, the introduction of the gravity probe and the making of counter openings by the trephine, both to search for the bullet and for drainage,

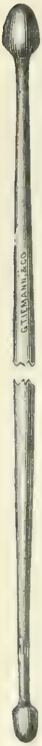

FIG. 1028.—Fluhrer's Aluminum Gravity Probe (full size, except length, which is twelve inches).

are the chief points in which recent practice differs from the old.

The cardinal principles to be applied to gunshot wounds may be stated as follows: First, the scalp should be shaved over a large area around the wound or wounds, or, better still, over the whole head.

Secondly, the entire wound should be disinfected, from the wound of entrance all the way to the wound of exit, or to the site of the ball, if the missile has not escaped.

Thirdly, if hemorrhage has taken place, either the wound of entrance or the wound of exit, or both, should be freely enlarged by the bone forceps or by the trephine, and the vessels secured by catgut ligatures, or, in rare cases, be controlled by pressure or by hæmostatic forceps.

Fourthly, the bullet or other missile should, if possible, be removed, if need be, by a second trephine opening.

Fifthly, absolute free drainage should be secured, again, if need be, by a counter trephine opening, even if the drainage tube should have to traverse the entire brain.

Sixthly, antiseptic or aseptic dressings should be applied, and the subsequent treatment of the case be conducted on general principles.

The admirable cases of Fenger and Lee, Fluhrer, Nancrede, Bryant, and many others since have proved conclusively the truth of the above maxims, and future wars will tell as different a story in cases of penetrating wounds of the head as they will in penetrating wounds of the abdomen.

Of the above points several have already been considered. The *removal of the ball* has always been one of the chief difficulties in cases of gunshot wounds. Fluhrer, in the brilliant article alluded to, however, showed a new method, which is of great importance. The wound having been suitably disinfected, together with, of course, the hands of the operator and the instruments, etc., the head of the patient is so placed that the probable direction of the ball will be vertical. The gravity probe of Fluhrer, made of aluminum, with large conical ends, is now introduced by its larger end. This probe is so light that it will not force its large end into the brain substance, and so produce a false passage, but by its own weight will follow the track of the ball, if this be made vertical. If the ball be within easy reach it may be extracted by the ordinary methods; if, however, as shown by the probe, it has penetrated so far as to be more accessible from the opposite side of the skull, unless important centres lie in the way a counter opening should be made on the opposite side of the skull at the point at which the probe would emerge if pushed through. The proper point for the counter opening can be best located by the point of intersection of the lines determined in various planes by the method described by Bryant. Figs. 1029 and 1030 show the method plainly. Before the probe has been introduced in the search for the ball its length should be measured. If, then, it impinges against the ball, by measuring the protruding part of the probe the difference in the two measurements will give the depth at which the ball lies. Pushing the probe through to the counter opening, and again measuring the part protruding from the original opening, we ascertain the depth at which the ball lies from the counter opening. The probe is now to be carried entirely through the counter opening and two strands of antiseptic silk are attached to its extremity, and on withdrawal of the probe the strands of silk will lie in the track of the wound. To one of these is now attached a No. 9 (French) gum catheter, which should be new and carefully disinfected, especially in its interior, and within it should be a disinfected straight stylet in order to give it rigidity. The stylet being ensheathed by the catheter will not mislead by its metallic sound or feel in the search for the metal ball. A pair of forceps is now tethered to the catheter by a loop of silk round one of its arms, and the ball is searched for at its known depth, above, then below, then to the right, and lastly, to the left of the catheter guide. Between searching in any one direction and the following one the forceps should be entirely withdrawn and reintroduced so as not to swing around the catheter and thereby, perhaps, injure the brain substance unnecessarily. In case the ball has struck the opposite side of the cranium, as in Fluhrer's case, it will have rebounded in the direction determined by two influences: first, the natural angle of reflection, which will probably be about equal to the angle of incidence; and secondly, the influence exerted by gravity. A counter opening having been made, the wound in the meninges made by the ball in impinging on the opposite wall of the skull should be sought for, and from this, as

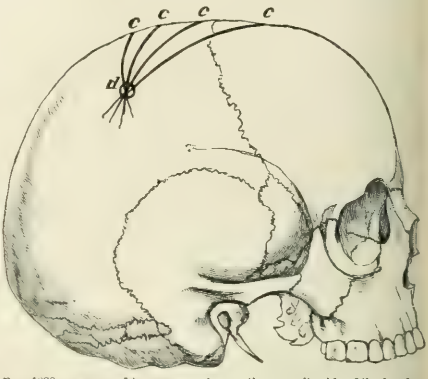

FIG. 1030.—*c, c, c, c*, Lines converging on the opposite side of the head; *d*, point at which to trephine.

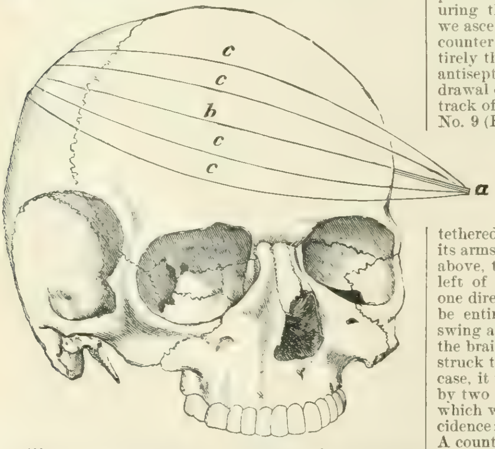

FIG. 1029.—*a*, The extra-cerebral portion of the probe; *b*, the line taken by the probe through the brain; *c, c, c, c*, lines placed in the direction of the probe with the aid of a string.

a new point of departure, a new search may be made in the same manner as above with the gravity probe. Another instrument may be used, also, in determining the site of the ball. It is the very ingenious invention of Dr. Girdner. The "telephonic probe," if it touch the ball, will indicate it by a grating sound, a sound which is not produced if it touch any other than a metallic substance.

By the second strand of silk a drainage tube may now be drawn entirely through the wound.

Until recently missiles that lodged in the brain were allowed to remain there unless easily accessible, under the impression that meddling with the brain with a view of removing anything that may have lodged was entirely unwarrantable. This, we now know, is an error. The missile should in all cases be removed if accessible. Dr. Wharton has presented the analyses of 316 cases in which foreign bodies were lodged in the brain. As a result of this investigation, in 106 cases in which removal was effected, 34 (32 per cent.) died. Of the much larger number, 210, in which the missile was not removed, 122 (58.1 per cent.) died, and of those who lived 10 died from the ultimate effects of the ball, and many of the others suffered from epilepsy and physical and mental deterioration.

Arnold, at the request of Bryant (*loc. cit.*), investigated very carefully 140 cases, and found that of the 85 cases in which the missiles escaped primarily, or were removed, 38 (44.7 per cent.) died. Of the 55 in which the missile was not removed, 32 (58.2 per cent.) died, giving nearly the same result as Wharton's tables.

If the bullet has not escaped, and cannot be found or removed directly, or by a counter opening, the wound should be carefully disinfected and thorough drainage should be secured by a rubber tube carried to the entire depth of the wound. If, however, a second opening has been made, the drainage tube should be carried entirely through the track of the wound.

Drainage should be kept free and thorough, and antisepsis secured by gentle syringing with sterile salt solution, but it should be done with great gentleness.

FRACTURE OF THE BASE OF THE SKULL.—Besides the ordinary dangers from fracture of the vault of the skull, we have at the base another danger of great importance, that does not at first glance seem to be present, viz., probable and insidious communication with the external air, and, as a result of it, septic infection that is apt to be overlooked. This communication with the outer air may take place through the ear, the nose, the mouth, or the roof of the orbit.

Fracture of the occipital bone, involving the base of the skull, should be dealt with, of course, as in the case of fracture of the vault.

Heretofore fracture of the base has been excessively fatal, and it is a remarkable fact in cerebral surgery that Wagner, in the lecture already referred to (page 421), states that in twenty-three cases of fracture of the base that survived the first forty-eight hours (that is to say, those which did not die from the severe primary violence), every one of them recovered.*

If the communication with the air be through the ear, as shown by escape of the cerebro-spinal fluid, the first thing to do is most carefully to disinfect the ear, after having removed all of the wax, dirt, etc., within it. This disinfection should extend to all the hollows in the external ear and the surrounding scalp, which last should be shaved. The ear should next be well washed out with boric acid solution, and the ear and scalp should then be covered with sublimate gauze.

Should the fracture of the base involve the roof of the orbit and not communicate with the external air, of course it should be treated as a simple fracture without operative measures, unless the subsequent history should demand it. But should such a fracture be caused by an umbrella rib, a splinter of wood, a pair of scissors, or other such vulnerating body, then the whole region about the orbit should be carefully disinfected. After disinfection by bichloride solution (1 to 1,000) the normal salt solution should be used. An incision should then be made in the line of the eyebrow, in order to hide the subsequent scar, the lid drawn down, the track of the wound carefully disinfected, and a considerable opening made in the roof of the orbit by a gouge or chisel, rather than by a trephine. If the brain itself has been injured, the dura should be opened, and the track of the wound again disinfected. Thorough free drainage should be provided for, and the wound treated as usual.

Should the fracture involve the nose, the same principle would apply, viz., thorough disinfection and free drainage. Trephining here should be through the track of the exterior wound, if it involve the base of the nose or lower forehead. If the vulnerating body has passed through one nostril, of course the nostril should be first washed clean and then disinfected with boric acid and salt solution, and, after trephining, the same acid should be thoroughly insufflated into the nostril, both from below and by way of the trephine opening. The trephining would probably be done best just above the root of the nose, and would, unfortunately, involve the frontal sinus, which should always be avoided if possible. But the great danger from want of drainage must overcome every objection of a minor character. The frontal sinus, as well as the wound, should be disinfected, therefore, with great care, and the same drainage and dressing be applied as heretofore recommended. In order to prevent the passage of infective air through the nose, both from without and from the lungs, it would be well to plug up both anterior nares with a moderate tampon of sterilized cotton for the first three days at least. A tampon in the anterior nares would nearly prevent any current of air through the nose, even from behind. In children it is to be remembered that the frontal sinus is very small and ill developed.

INTRACRANIAL HEMORRHAGE, ESPECIALLY FROM THE MIDDLE MENINGEAL ARTERY.—Three papers published some years ago practically settled the question of the treatment of hemorrhage from the middle meningeal artery (Wiesmann, ***Deutsche Zeitschr. f. Chir.***, Bd. xxi. and xxii., 1885; Jacobson, "Guy's Hospital Reports," 1886, vol. xliii.; and Krönlein in the first journal, Bd. xxiii., Heft 3 and 4, 1886).

The violence that may rupture the middle meningeal is but slight in some cases; so slight, indeed, as even to leave no mark. A fracture may exist, but it may be so small as not to be recognizable by the touch, and barely by sight. In a number of cases there will be no fracture whatever. Stokes reports a case which is a model of diagnosis and treatment, in which, after only a bruise, trephining evacuated a clot an inch and a half thick, followed by immediate relief to the paralysis, and speedy recovery. Jacobson (*loc. cit.*) reports four cases out of seventy, of such hemorrhage, in which no fracture existed. A number of other cases have since been reported. In some, of course, the fracture will be both visible and palpable, not only over the vault but also at the base of the skull. Either the trunk or the branches may be ruptured. Of the seventy cases tabulated by Jacobson, in two certainly, and in four others probably, the trunk was injured; but the divisions beyond the trunk are the site of the lesion more commonly than is the main trunk itself.

The adhesions of the dura to the skull, it should be remembered, while in general very strong, are very slight in the area of the middle meningeal, as pointed out by Tillaux, and so favor hemorrhage.

The symptoms of the greatest value are: First, an interval of consciousness between the accident and the appearance of serious symptoms. This interval of consciousness is of the greatest importance, and probably is worth all of the other symptoms put together. It is due to the fact that it takes a certain amount of time for sufficient blood to escape to produce unconsciousness from pressure. It was present in two-thirds of Jacobson's cases. If the main trunk be injured, or one of its larger branches, and the blood poured out rapidly, this interval will be very brief, and coma and death will quickly supervene. It may even be absent, the secondary coma setting in before the primary unconsciousness has disappeared. But not uncommonly it will last for some hours, or occasionally even for days. But even if brief, its possible existence should always be inquired into, and if present the other signs of intracranial hemorrhage should be looked for with care. Secondly, there is hemiplegia on the side opposite to the hemorrhage. This may be progressive, the hemiplegia extending from one portion of the body to another, as the extending clot presses upon one cortical centre after another; as, for example, if the clot be effused over the face centre, the face muscles will be paralyzed first, and as the blood clot extends upward over the arm centre, paralysis of the arm will follow. Such extension is extremely significant. The paralysis, however, may exist on the *same side* as the *injury*, if the artery has been ruptured on the side opposite to the injury, as has not infrequently happened. Clark, in just such a case, trephined on the same side as the injury and the paralysis, and lost his patient, who had a clot in the side opposite to that of the injury. Sometimes, though rarely, both arteries may be ruptured, as in the remarkable cases of Hill (Cases 18 and 19, Jacobson's paper). If there be no paralysis, the dilated and immobile pupil on the side of the clot may assist the diagnosis. This was the only diagnostic sign in one of my cases. Thirdly, the pulse becomes frequent. Fourthly, the respiration becomes slow and stertorous. Fifthly, if the clot extends toward the base, the pupil on the side of the clot will be dilated and immobile, and if the clot be on the left side, aphasia also will take place. Sixthly, the temperature will probably rise, it may be quite rapidly, and up to 101°–103°, or even 104° F., especially on the side opposite to that of the clot, according to Horsley.

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* It is impossible, however, on the mere *ipse dixit* of Wagner, to accept the diagnosis of *all* these cases as undoubted fractures of the base, without detailed histories.

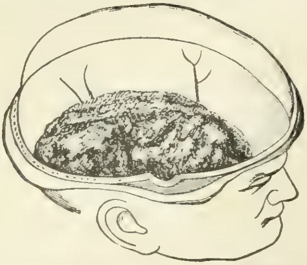

FIG. 1031.—Clot in Hemorrhage from the Middle Meningeal Artery. (Jacobson.)

The importance of operative treatment is best shown by Wiesmann. Of 147 cases treated expectantly, 131 died (89.1 per cent.); of 110 cases treated actively, only 36 died (32.7 per cent.)! Besides this, in the majority of these cases ending fatally after operation, the *extravasation was not reached, and the clot therefore was not removed.* When, therefore, any of the above symptoms are present in a case showing a reasonable ground for believing that the middle meningeal or its branches have been ruptured, even though some doubt exist, the skull should be trephined.

As to which side of the skull should be operated upon, we should be guided by the localizing symptoms rather than by the site of the injury. Krönlein (Fig. 1032) trephined four cases of rupture of the middle meningeal, and in two of them removed the clot, and the patients recovered. In the other two he failed to find it, and both patients died. He states that in by far the greatest number of cases the clot will be best reached by trephining at a point one inch behind the external angular process of the frontal bone, at the level of the upper border of the orbit. Should this not reach the clot, he strongly urges that another trephine opening be made just below the parietal boss on the same level as the former. By not making this last opening he lost the two patients alluded to. By the anterior opening access is had to the main trunk and the anterior branch of the middle meningeal, and by the posterior to its posterior branch. As in not a few cases there will be doubt as to whether the rupture is in the anterior branch or trunk, or, on the other hand, in the posterior branch, the need for the second opening, in case the first does not disclose the clot, is apparent. Having made one or both of these openings, the clot should be removed, and either opening, if necessary, enlarged by the rongeur forceps in order to obtain access to it. If the pupil be widely dilated, showing that the clot has extended downward toward the base, the trephine should be applied about half an inch below the level of the upper border of the orbit, rather than at its level.

Should the middle cerebral artery be wounded, it must be secured by ligature. The differential diagnosis cannot be made at present between hemorrhage from the middle meningeal and that from the middle cerebral; hence the discovery that the middle cerebral is wounded would follow a trephining at the point already indicated for the meningeal—viz., an inch behind the external angular process. If the bleeding point on the middle cerebral be not accessible here, as the artery lies in the fissure of Sylvius, the trephine opening should be enlarged by the rongeur forceps, upward and backward, in the line of the fissure, *i.e.*, in the direction of the parietal eminence.

The clot cavity should be washed out, after the hemorrhage has been controlled, by normal salt solution. Drainage should be carefully provided for, and the wound dressed in the usual way. Weir, in May, 1885, was the first, I believe, to propose that in case the first trephine opening would not answer well for drainage, a second one should immediately be made. In doing so, not only must the position of the clot be remembered, but the second trephine opening should be made also in such a position as to favor drainage in the recumbent posture. As a secondary measure, it was done by Noyes as early as 1882, and later by many others.

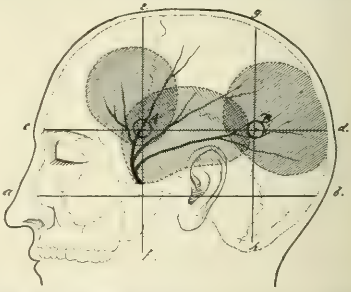

FIG. 1032.—Site of Trephine Opening to Reach Clot in Hemorrhage from Middle Meningeal Artery. (After Krönlein.) *a*, *b*, Horizontal line through the auditory meatus; *c*, *d*, line passing through the eyebrows; *e*, *f*, vertical line 3 or 4 cm. behind the external angular process; *g*, *h*, line passing through the posterior border of the mastoid process; *A*, the point where the anterior branch of the middle meningeal artery can be reached; and *B*, the point where the posterior branch of the same artery can be reached. (Esmarch and Kowalzig.)

Under the head of hemorrhage should be mentioned, also, a remarkable and instructive case, reported by Dr. T. Grainger Stewart and Mr. Annandale, of traumatic pachymeningitis interna, accompanied by hemorrhage.

In consequence of a fall on the occiput, without visible lesion of the skull or scalp, in two months there were gradually developing vertigo and frontal pain, increasing optic neuritis, gradually developing stupor, right hemiplegia and aphasia, with subsequent normal temperature. Annandale trephined over Broca's convolution, and found under the dura a space extending three inches behind and two inches in front of the trephine opening, which was filled with brownish-red fluid. Temporary improvement occurred, but the patient died five days later. The autopsy showed inflammation of the cerebellum, diffused lepto- and pachymeningitis, with hemorrhage of the cerebrum on both sides and red softening on the left side. This was evidently of inflammatory origin, and it is not improbable that in such a case as this, and in those of serous apoplexy, very early trephining might result far differently.

Ceci (quoted by von Bergmann, *loc. cit.*, p. 112) also has reported a case of chronic hemorrhagic pachymeningitis, the result of a blow, in which palsy, incontinence, and coma were present. He trephined over two months after the accident, evacuated the blood, and his patient recovered and regained all the motor functions except those of the left hand (slight paresis).

In the *British Medical Journal*, March 2d, 1889, Spencer and Horsley report some remarkable experiments on the possibility of controlling hemorrhage from the middle cerebral artery and its branches by pressure on the carotid. The ingravescent form of apoplexy from such a rupture, impending apoplexy from intense cerebral congestion, and some of the severer congestive headaches may possibly prove capable of relief by this means. The reader must consult the original paper for the grounds upon which their conclusions are based. I have operated on two such cases and saved one.

Inveterate Headache.—Horsley (Case 7 of his table) and von Bergmann (*loc. cit.*, p. 113) have published two cases of relief of fixed and excessively severe localized headache by operative interference. In Horsley's case he trephined at the seat of pain and removed a piece of the parietal bone, the inner table of which had been perforated and was being eroded by a Pacchionian body. Relief from pain had continued for five months after the operation.

In von Bergmann's case, after all ordinary means had been exhausted, the bone was exposed. Its color was dark and purplish, as if extravasated blood were seen through it. It was greatly thinned, so that he was able to cut it with his scalpel. A quantity of tea-like dark blood escaped, and the pulsating dura was seen beneath. Six months before the operation a stone had struck the patient on the head, without, however, wounding the skin. This had been followed by considerable localized swelling, and the headaches began some weeks after the injury. As soon as he recovered from the effects of the anæsthetic his headache was gone, and the relief had continued for certainly three years. I have operated on four such cases with resulting cure in three.

Such operations seem, therefore, to be entirely justifiable in view of the very small risk to life from trephining; provided, of course, that the headache be really so constant and severe as to justify a reasonable risk, and that all suitable medical means have been faithfully and ineffectually tried. Very probably simple trephining without opening the dura may be all that is necessary to effect the cure. In cases of suspected syphilis, the iodides should be pushed on the American plan, if necessary, up to half an ounce a day, before a decision in favor of operation can properly be made. Just such a persistent, severe headache (of syphilitic origin) has recently been under my care, and has in this way been cured, and an operation avoided; less than three drachms a day, it was found, did absolutely no good.

Mental Disturbances.—Macewen has reported a remarkable case of this kind. The man had received an injury a year previously, and was suffering from melancholia, with homicidal tendencies. These were attended by paroxysms of pain, which were not well located. There were no motor phenomena, but it was discovered that immediately after the accident, for two weeks, he had suffered from psychical blindness. He could see, but what he saw conveyed no impression to him. He recognized his New Testament by touching its smooth leather cover with the deep indented letters on the back, but on opening it the printed words were unknown symbols to him. At the operation the angular gyrus was exposed, and it was found that a portion of the inner table had been detached and had produced pressure on the posterior portion of the supramarginal convolution, while a corner of it lay embedded in the anterior portion of the angular gyrus. The bone was removed from the brain and replaced in its proper position. He was greatly relieved from his mental state, though still excitable. He was at work when the case was reported, and had made no further allusion to his homicidal tendencies. This localization of a single mental process is of great importance. The fact that Macewen was able, by a careful and shrewd examination, to elicit so important a localizing symptom from a case which was obscure both in its history and in its visible lesions, is a source of great encouragement.

Besides the case just alluded to, in which psychical symptoms led to the localization of the lesion, there are a number of cases on record in which insanity has followed injury and has been cured by operation involving the brain. One is reported by Hoffman: A man, fifty years of age, was made unconscious by a blow on the head, which, however, produced neither fracture, convulsion, nor paralysis, but was followed by pain in the head and aphasia, and a tender spot above and in front of the right ear. Insanity developed after healing. The cranium was opened by a chisel over the tender spot. The dura bulged but did not pulsate. An incision evacuated a half-ounce of cerebro-spinal fluid. The brain tissue had been lacerated by the blow. The patient recovered both from the operation and from his mental alienation.

McDonald reports a case of insanity following a pistol wound. The wound was three-eighths of an inch to the right of the middle line, and at the junction of the anterior and middle thirds of the first frontal convolution. The skull was opened eighteen months after the injury. There was no bone, but only fibrous tissue, at the point of injury. At the fourth puncture by a hypodermatic needle, two drachms of serum were removed. On recovery from the anæsthetic the patient had regained his sanity.

Bennett and Gould report the case of a man who received a severe blow two and three-fourths inches behind the meatus, and three and one-half inches to the right of the middle line. Six weeks afterward epilepsy developed, followed by mania, so that he was placed in an asylum. Trephining was done and the brain explored, in three or four different directions, to the depth of one inch, but nothing was found. The patient recovered both from his epilepsy and from his insanity.

Rannie reports the case of a woman who had tertiary syphilis. For eighteen months she had suffered with frontal and parietal pain on the right side, with tenderness of the scalp and discharge from the right ear, all of an intermittent character. There was no evidence of disease of the middle ear. She also suffered from visual hallucinations and melancholia. Her disease finally culminated in epilepsy affecting chiefly the left side, including the face. The attacks were followed by marked paresis on the left side. She was trephined over the right pre-Rolandic convolution. The skull and the dura were thickened. On opening the dura a small quantity of purulent fluid ran out which was found to come from a small degenerating gumma in the dura. Very slight opacity of the membranes existed. Three weeks later she was walking without any droop, and the motor power of the left arm was steadily improving. The headache and tenderness of the scalp had disappeared, and her mental condition was very much improved.

A large number of similar instances have been since reported. While there have been many failures, the successes have been considerable, quite enough to warrant surgical interference in suitable cases.

TREPHINING FOR ARRESTED DEVELOPMENT.—As a rule it is better to leave these cases alone. Extravagant claims and promises have been made by some surgeons, but they have not been realized in practice.

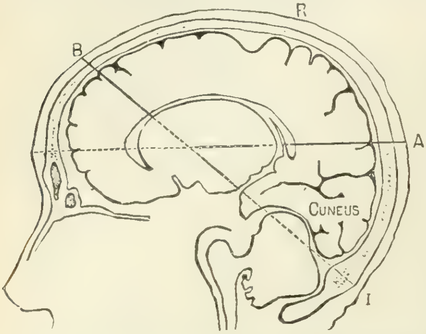

FIG. 1033.—(Drawn by Dr. John M. Taylor.) Antero-Posterior Section of the Head One-Half Inch from the Middle Line. R, Fissure of Rolando; I, inion; A and B (solid), the lines of puncture, the dotted lines showing their imaginary continuation to the opposite fixed points.

TAPPING OF THE LATERAL VENTRICLES AS A DEFINITE SURGICAL PROCEDURE.—In November, 1888–89, I first proposed the tapping of the lateral ventricles as a definite surgical procedure. Since then it has been done scores of times and as a rule with benefit. I had hoped that it would serve the same purpose as celiotomy for tuberculous peritonitis. The few cases in which this fatal disease has been thus treated have proved that it is of little use. But it has been of great use as a palliative measure for the relief of the intense headache accompanying especially tumors pressing on the veins of Galen and the straight sinus. Moreover, the operation has dispelled the idea that opening the lateral ventricles is necessarily fatal. In a paper read at the International Medical Congress in Berlin in 1890 (*Lancet*, September 13th, 1890, New York *Medical Record*, September 20th, 1890), but unfortunately published only in abstract, as the original was lost by the secretary, I quoted many cases of such a lesion followed by recovery.

Operative Technique.—In doing the operation it is clear that we must avoid the motor zone, Broca's centre for speech, and any other well-defined centres for the special senses, and also the regions of the large blood-vessels of the brain, the middle meningeal, and the middle cerebral arteries. A number of experiments on the cadaver led me to point out three practicable routes for the purpose. They are all, of course, only provisional, until experience shall show us a better one.

First, from a point from one-half to three-fourths of an inch on either side of the median line, and one-third of the distance from the glabella to the upper end of the Rolandic fissure. This is high enough to avoid the frontal sinuses, and is in advance of the motor area. A three-quarter-inch trephine opening having been made and the dura having been incised crucially, a grooved director should be thrust slowly into the brain tissue in the direction of the inion. The director will traverse the first frontal convolution. At a depth of two to two and one-fourth inches the normal ventricle will be reached. Should it be distended, it would be reached at a less depth.

Secondly, trephine, etc., as before, midway between the inion and the upper end of the Rolandic fissure, one-half or three-fourths of an inch from the median line. This is high enough to avoid the cuneus, the wounding of which would produce hemianopsia. The director should now be slowly thrust into the brain toward the inner end of the supraorbital ridge on the same side. The director will traverse the precuneus, and the normal lateral ventricle will be reached at a depth of two and one-fourth to two and three-fourths inches from the scalp. A distended ventricle will, of course, be reached at a shorter distance.

Thirdly, trephine, etc., as before, at a point an inch and a quarter behind the external auditory meatus, and one inch and a quarter above Reid's "base line." This will expose the second temporal convolution. It is possible that this may be the site for hearing of the opposite ear, but it has been punctured in a number of cases of abscess in the temporo-sphenoidal lobe without apparent injury to hearing. The director should be carefully thrust into the brain in the direction of a point vertically over the opposite meatus, and two and one-half or three inches above it; when at a depth of two or two and one-fourth inches the normal lateral ventricle would be reached, either at the beginning or in the course of the descending cornu. I have advised the use of the director rather than the hypodermatic needle, for the reasons already stated in the section on abscess of the brain. The fluid having been found, a bundle of horse hairs or a drainage tube should be inserted for a suitable length of time. In order to prevent possible loss of the drainage tube in the cranial cavity, it may be passed through a buttonhole opening in the flap, and, if necessary, be secured to the flap by a stitch. To regulate the amount of drainage through the tube it may be closed by a disinfected wooden plug. In this a **V**-shaped slot may be cut, and the size of the slot will regulate the rapidity of the drainage. Whether the drainage shall be continued for more than twenty-four hours, a longer experience must decide,

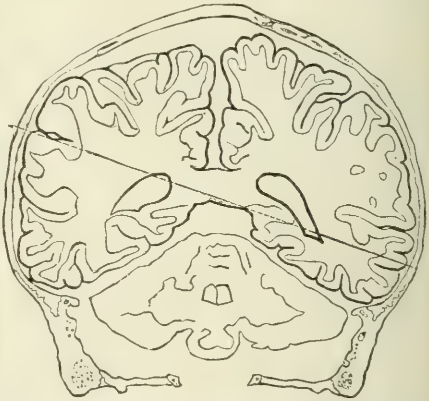

FIG. 1034.—(Drawn by Dr. John M. Taylor.) Transverse Section of the Head One Inch and a Quarter Behind the Meatus. The continuous line shows the line of puncture, the dotted line its imaginary continuation to the opposite side of the skull.

Of the three proposed routes my preference is for the lateral opening. This route has a great advantage in that by it we can explore for abscess of the temporo-sphenoidal lobe, and also for effusion into the ventricles, by the same trephine opening. The drainage could be either favored or hindered by the patient lying with the operated side down or up. Should prolonged drainage prove to be wisest, the posterior route might be the best one. The anterior route would hinder drainage, and as an additional disadvantage there would be a visible scar. As to a choice of which side it is best to operate on, we should select the side of the diseased ear, if there be such disease, or if not, then that side which is tender to either pressure or percussion, or both.

After the above was written my attention was called to the fact that Wernicke, so long ago as 1881, proposed to tap the ventricles, and that Zenner renewed the proposal. At the time of writing my paper I was wholly unaware of their propositions, and in referring to them I find that, while I must disclaim priority for the suggestion, I may claim that I have established exact rules for the operation and described its precise technique.

January 11th, 1889, in my clinic at the Woman's Hospital, I first performed the operation. I found it easy, and the rules I laid down proved to be correct. The patient was a fat and hearty boy, of four, suffering, it was thought probable, either from tumor or chronic meningitis with effusion, most likely a tumor of the cerebellum pressing on the straight sinus or the veins of Galen. There were no symptoms by which it could be more accurately located. His head had begun to enlarge about the early part of December, 1888, and measured twenty-one and three-eighths inches in circumference (exactly the measurement of my own head), with a biparietal diameter of six and one-fourth inches. At Christmas he became blind. For this he was brought to Prof. George Strawbridge, to whose courtesy I owe the case. There was great choking of both discs and threatened blindness. The general health was good, and the temperature was normal. As the approaching blindness from the increased intracranial pressure was the immediate danger, I decided, with Dr. Strawbridge's assent, to tap the ventricles, and selected the lateral route. I removed a one-half inch button of bone, one inch and a quarter behind the left meatus and one inch and a quarter above Reid's base line. The dura pulsated and bulged. In the dura as in the skin, I made a small crucial incision. I then slowly introduced a hollow needle (of the size of No. 5 of the French catheter scale), into which I had already pushed three doubled horse hairs nearly to the end. I introduced it toward a point two and one-half inches above the right meatus. At a depth of an inch and three quarters from the dura I suddenly felt a marked diminution of the pressure, and said to the class that I believed I had entered the ventricle, and in a moment the fluid began to escape. This fluid was found to contain sugar and albumin. It was slightly turbid, with small flakes in it.

The horse hairs were now pushed in as the tube was pulled out. About three ounces of fluid escaped during the operation. An ample sublimate dressing was applied. During the first week from two to four ounces escaped daily, and the choking of the discs diminished from 2.30 to 1.09 mm. in each eye, the decrease being *measurable from day to day*. At the end of the first week I explored for a possible tumor by thrusting a probe in two directions into the left occipital lobe to the depth of three and a half inches. Finding no tumor I made a small opening, by a simple gouge, in the occipital bone, below and to the left of the inion. Through this I probed the left lobe of the cerebellum to a depth of two inches, and then obliquely across into the right lobe two and a half inches, but found no tumor. There was no reaction from these procedures, and the wound healed promptly. At the end of the second week the choking was reduced to 0.96 mm. As in spite of the drainage the swelling was subsiding very slowly, and Dr. Amy S. Barton, who kindly examined the eyes for me, reported that there was beginning atrophy of the nerves, I removed the horse hairs and introduced a small rubber tube into the ventricles. For a week this gave vent to from four to eight ounces of fluid daily. Except a temporary rise of temperature, no reaction followed. At the end of four weeks, as the boy's general condition had deteriorated, especially when from choking of the tube the drainage was poor, I removed another similar half-inch button at a corresponding point above and behind the right ear. I then explored the right occipital lobe as far as to the tentorium and falx, but found no tumor. I therefore tapped the ventricles from the right side by a drainage tube. Following this, there was a brief but sharp rise of temperature to 104° F., which, however, quickly subsided. Four days later I washed out the ventricles from side to side by eight ounces of a warm boric acid solution (gr. iv. to ℥ i.), evidently to the boy's comfort, and with no results of a deleterious character. The boy died fifty-two days after the first operation. The autopsy showed that at the site of the drainage tubes, even after so long a time, there was not the slightest trace of inflammation either on the cortex or in the ventricular cavities, and the cerebro-spinal fluid evacuated at the autopsy was less turbid than that evacuated at the operation. There was not any perceptible trace of the various punctures. The cause of death was a tumor of the cerebellum. The probe had penetrated it, but as its density was about the same as that of the brain, its presence could not be appreciated.

The case showed clearly that the rules which I formulated for the operation are exact; that the procedure is easy and safe; and that the ventricles may not only be drained, but even irrigated, without causing any deleterious results. (For bibliography see Note at end of volume.) *W. W. Keen.*

BRAIN: SYPHILIS.—Syphilis of the brain may develop as the result of inherited syphilis, or during the secondary or tertiary stage of the acquired disease.

In hereditary syphilis the evidences of an affection of the brain are manifested, as a rule, during childhood. According to Fournier the disease begins generally between the ages of three and eighteen years. In rare cases, however, it is observed in early childhood. For example, marked arterial changes were presented by a girl of fifteen months suffering from hereditary syphilis. In this case the dura mater was smooth and pale, the pia mater presented numerous circumscribed patches of thickening over the cerebral lobes. There was slight thickening around the large arteries at the base of the brain, and most of these vessels were thickened and hard. The basilar artery was completely plugged, and the upper part of the vertebral arteries contained tolerably soft thrombi.

On the other hand Ljunggren reports a case, beginning at the age of thirty-three years, which he attributed to hereditary syphilis.

In any event, however, hereditary syphilis is a comparatively rare source of cerebral disease. It was formerly held that, in acquired syphilis, nervous manifestations were observed almost exclusively among the very late symptoms. Many neurologists now hold the very opposite opinion, and this view is also gaining ground among syphilidologists. So far as our knowledge goes, the earliest development of cerebral symptoms was observed by Brasch, who reported the following case: The patient, aged forty-three years, was infected with syphilis in the early part of August, 1893. In the middle of September, 1893, he had an attack of right facial paralysis and headache. In the beginning of November, 1893, he suffered from dizziness and headache and the paralysis was unchanged. In the beginning of December there was difficulty of hearing on both sides, and examination showed that this was probably due to labyrinthine disease. On February 19th, 1894, he was discharged, free from symptoms. In March, 1894, there was a return of the headache, vertigo, and difficulty of hearing. May 30th, left hemiplegia developed, but improved under antisyphilitic treatment. Then the condition grew worse, bulbar symptoms set in and the patient died on October 30th, 1894.

The autopsy showed purely vascular disease most marked at the base, but also present in other vessels. The hemiplegia was due to softening in the anterior part of the right half of the pons. The microscope showed advanced endarteritis syphilitica; secondary degeneration of the right pyramid from the pons lesion down to the cord; degeneration of both acoustic nerves in their extra-cerebral course, and disease of both ventral nuclei; both facial nuclei and roots were intact, but the right root exhibited, a short distance before its exit from the brain, an abundant development of spindle cells, while the peripheral nerve showed parenchymatous and interstitial changes.

While this case and other similar but less striking ones prove conclusively that cerebral lesions may develop among the very earliest manifestations of the constitutional disease, we still adhere to the older view that in the majority of cases syphilis of the brain is a late manifestation. Indeed, the symptoms of secondary syphilis very often are entirely or almost entirely absent, so that we may be compelled to rely upon the grouping of the cerebral symptoms in arriving at a diagnosis of the previous infection. Numerous cases have been reported in which twenty, thirty years or more have elapsed between the initial lesion and the outbreak of the cerebral symptoms.

In addition to the direct etiological significance of syphilis in the production of brain disease, it also seems to exert a malign influence after the constitutional disease has run its course (parasyphilitic affections of Fournier). This is seen particularly in dementia paralytica and locomotor ataxia. In the large majority of such cases a previous history of syphilis can be elicited, but the diseases are distinguished from syphilitic affections proper both by the character of the anatomical lesions (purely degenerative) and by the utter uselessness of antisyphilitic treatment. In these diseases we assume the existence of a primary degenerative process, resulting from a chemical poison which has been produced by the syphilitic germs (metasyphilis or parasyphilis). It is not true, however, that dementia paralytica is always the result of constitutional syphilis.

Among the exciting causes which may lead to localization of the syphilitic virus in the brain may be mentioned mental overwork and prolonged worry, injury to the head, and alcoholism.

PATHOLOGICAL ANATOMY.—Syphilis may attack the bones of the skull and all of the structures within the cranial cavity, the vessels, meninges, or brain tissue, either singly or in combination. The lesions are usually multiple in character.

One of the most frequent forms of cerebral syphilis is a lesion of the vessels, which attacks usually the vessels at the base of the brain or their large branches. The disease may begin independently in these vessels or it may spread from adjacent foci of disease in the meninges.

Heubner, who was the first to call attention to specific lesions of the cerebral vessels, describes them in the following words: The vessel becomes less transparent and somewhat whitish, finally grayish white; it then becomes cylindrical in shape and very rigid. Upon transverse section the lumen of the vessel is found narrowed by new-formed tissue which develops between the elastic lamella of the tunica intima and the endothelial layer. The new tissue consists at first of endothelium cells which continue to proliferate and change into a firm connective tissue consisting of spindle and stellate cells into which round cells emigrate from the nutrient vessels of the artery.

While this endarteritis of Heubner has also been observed by other writers, changes of a periarteritic and mesarteritic character have been frequently described.

According to Baumgarten, the process begins, as a rule, in the outer layers of the vessels as a gummatous periarteritis, while the intima is only affected secondarily by proliferation of cells. He found little yellowish tumors (from the size of a poppy seed to that of a cherry pit) upon the arteries, meninges, and cerebral nerves; they consisted of granulation tissue and were associated with endarteritic changes in the intima. Gummatous arteritis has also been observed by other writers.

Koester claims that the process starts from the vasa vasorum of the external layers of the artery, and that the leucocytes emigrating therefrom form inflammatory foci in the muscular coat. The affection begins, therefore, as a mesarteritis while the endarteritic proliferations develop secondarily by immigration of cells from without.

According to Abramov, all three layers of the vessels are attacked independently of one another. Dilatation of the vessel may be produced by destruction of a circumscribed part of the vascular wall from proliferation starting either in the external or in the internal layer. If the proliferation starts in the tunica intima, a dense accumulation of elastic tissue is produced, due to splitting of the fenestrated membrane. Abramov came to the conclusion that the microscopical findings are insufficient to prove the syphilitic character of the vascular disease, unless gummy nodules are found in the walls of the vessels.

Hyaline degeneration has also been described in the small vessels of the brain.

Gummata constitute another frequent form of syphilitic lesion of the brain. As a rule, these tumors start from the meninges or the prolongations of the latter into the brain substance. In exceptional cases, the gumma is located in the central ganglia or other parts within the brain, but it is probable that even in these cases they start from prolongations of the pia mater.

In the large majority of cases the tumor is situated on the meninges of the convexity and at the base of the brain. They vary in size from that of a pin's head to that of a walnut or even hen's egg. The miliary form is rare and may be mistaken for miliary tubercles.

Gummata belong to the class of infectious granulomata, *i.e.*, they are composed of granulation tissue or densely aggregated round cells. The connective-tissue stroma is very scantily developed. The smaller tumors may exhibit a uniform grayish or grayish-red color, but the larger ones are speckled with yellowish foci. A few stellate and spindle-shaped cells are found among the round cells. The yellowish foci are the result of simple necrosis of the round cells or caseation, and this is due to the relatively small number of vessels and the consequent poor nutrition of the parts. Some of the cells are also apt to be converted into firm connective tissue, which traverses the tumor in broad bands.

In cerebral syphilis we also find a diffuse gummy inflammation of the meninges, and this may or may not be associated with the presence of circumscribed gummata. This process is situated most frequently at the base of the brain and is often most marked over the optic chiasm. The pia mater in this locality is found thickened in varying degrees; in places the thickening is quite soft, in other parts it is firm and dense. This process surrounds the nerves at the base and sometimes compresses them, or the round-cell infiltration may spread into the tissue of the nerves. The process may also extend into the vessels of the circle of Willis. Usually the cortex is adherent to the pia mater, and the former is torn when an attempt is made to detach the meninges.

Gummy meningitis is also not uncommon at the convexity of the brain, but here it is more apt to start from the dura mater. This is perhaps owing to the fact that gummy tumors start not infrequently from the inner surface of the vault of the cranium. Apart from the specific lesions which we have just described, the brain may also exhibit secondary lesions, such as hemorrhage and spots of softening, varying in extent according to the character of the primary lesion.

The heterogeneity of the lesions of cerebral syphilis is increased still further by the fact that the spinal cord may also be the site of syphilitic processes.

Some writers also maintain that syphilis may give rise to ordinary, non-specific inflammatory processes in the brain, such as Virchow's encephalitis of childhood, spots of softening, and chronic disseminated foci of inflammation. None of the reported cases, however, seems to be entirely free from doubt.

In quite a considerable number of cases it has been demonstrated that syphilis has given rise to degenerative processes in the nuclei of various cerebral nerves (nuclei of the ocular muscle nerves, glosso-pharyngeal nucleus, trigeminal and acoustic nuclei).

SYMPTOMS.—It is evident from our brief résumé of the pathological anatomy of cerebral syphilis that the symptoms must vary greatly in character. Nevertheless, there are certain prodromal symptoms which may be common to various forms and localizations of the disease.

The most prominent prodrome is headache. This is always present when syphilis attacks the bones of the skull, but is also frequent when the osseous structures are unaffected. For months it may be the sole symptom. The pain is usually of a boring, pressing, often agonizing character, with marked nocturnal exacerbations, as a rule, though it is not very infrequent to find the pain equally severe during the day. The pain is often so severe that it gives rise to persistent insomnia; but the latter symptom may also be present for a considerable period independently of the occurrence of pain. In not a few cases the headache is associated with attacks of dizziness and sometimes with vomiting. Sometimes the only prodrome noticeable for quite a while before the advent of other symptoms is an inexplicable fear "that something is going to happen," and this feeling sometimes causes great mental depression.

Paralysis of one or more of the ocular muscles may also be an early symptom. Sudden development and almost equally rapid disappearance of these paralyses are very characteristic of syphilis. Indeed, the sudden occurrence of ocular palsies in an adult, in the absence of other cerebral symptoms, should always lead the physician to make a very thorough examination into the question of their syphilitic origin.

Individual cases of syphilis of the brain present such a varied and heterogeneous history that it becomes extremely difficult to give a general description which will be applicable to any considerable group of cases. A tolerably well-defined symptomatology attaches to syphilis of the cerebral vessels, which we will first describe.

This form of disease is often preceded by headache, of the variety described above, which may last for a variable period, sometimes even for months, before the special symptoms develop. When the vessels supplying the pons or medulla are implicated, glycosuria or albuminuria may be associated with the headache. A characteristic phenomenon of a small series of cases is a peculiar drowsiness which may continue for several months and may precede or follow other evidences of disease of the vessels. The patients go about as if "in a haze"; their movements, both mental and physical, are slow and deliberate, as if consciousness, before struggling to the surface, had to overcome some unusual resistance. In some cases, deep coma develops from which it may be impossible to arouse the patient for days and days, or this condition may alternate with periods of delirium.

In a considerable proportion of cases the symptoms referable to disease of the vessels develop quite suddenly (sometimes as rapidly as in cerebral embolism) or within one or two days. The clinical history is then the same as that of embolism or thrombosis from other causes. The patient often develops hemiplegia, associated quite frequently with aphasia, if the paralysis is on the right side of the body. Aphasia may also be the sole symptom of an attack of this kind. In the majority of cases under our observation consciousness was retained either entirely or partially during the attack. Sometimes the duration of the paralysis is very brief and the patient is rapidly restored to the *status quo ante*. The entire seizure may be represented by a feeling of weakness or a sensation of numbness and tingling on one side of the body.

The hemiplegic attacks may be repeated from time to time. A patient under my observation had five attacks, in one of which both sides of the body were paralyzed in rapid succession. In cases of this kind, pseudo-bulbar symptoms are very apt to develop.

As a rule, the patient eventually suffers from symptoms indicative of other forms of syphilitic affections of the brain.

Gummy meningitis of the base of the brain also merits separate consideration. In this form likewise headache is a prodromal symptom and resembles in character the form described above. The headache is attended not infrequently with vertigo, which may appear either in paroxysms—the usual course—or may be more constant. Morbid conditions of sleep alternating with periods of excitement are also not uncommon prior to the onset of those symptoms which point more directly to a basilar affection. These conditions may also persist after the later symptoms have been fully developed. As a general thing they are manifested by semi-consciousness, from which the patient may be easily aroused or during which he performs various automatic actions. The return to complete consciousness may be quite rapid. At times the coma is quite complete and it is impossible to arouse the patient. In a case under our observation the patient remained completely unconscious for a week; this condition was unattended by stertorous breathing and the pulse was normal.

One of the most characteristic features of syphilitic basilar meningitis is the implication of the cerebral nerves, and chief among these is the motor oculi communis. In many cases both nerves are involved, and in the majority of cases a great part of the entire nerve supply is affected. As we have already stated, a single muscle alone may be paralyzed, and this is particularly apt to be the levator palpebræ superioris.

The trochlear and abducens nerves are attacked with much less frequency than the motor oculi. The pupils sometimes exhibit inequality; myosis or mydriasis may be present in one or both eyes. The Argyll-Robertson pupil has been observed frequently and is sometimes the sole indication, for a long period, of a cerebral affection. In one case under our observation, the right pupil was normal while the left showed the Argyll-Robertson symptom.

The optic nerve is not infrequently the site of disease and may exhibit the appearances of choked disc or simple optic atrophy. In the majority of cases these processes are due to an extension of the syphilitic lesion directly to the optic chiasm or nerves, or to compression of these parts. In a considerable number of cases hemianopsia is observed. This may persist unchanged or there may be a gradual development of complete blindness, the latter being limited generally to one eye. Temporary amaurosis, sometimes lasting only a day or two, is observed not so very rarely in this form of the disease.

In comparatively rare cases the other cerebral nerves may be affected, either separately or, more frequently, in varying combinations. The olfactory and trigeminus nerves are especially apt to be involved. The paralyses due to lesion of these nerves are always peripheral in character.

As we have already seen in the section on Pathological Anatomy, gummy meningitis is very apt to be associated with lesions of the vessels of the circle of Willis. When this happens, the clinical history is complicated by the symptoms described on page 244. The hemiplegia produced under such circumstances is combined, more frequently than in paralysis due to other brain lesions, with hemianæsthesia and hemianopsia. The morbid conditions of sleep and unconsciousness, to which we have already referred, are frequently present in this form of the disease, and general impairment of the mental faculties is not uncommon.

Gummy meningitis of the convexity of the brain is often found independently of lesions of other parts of the organ. This process starts with comparative frequency from the inner table of the skull or the dura mater, and may or may not complicate a well-defined gummy tumor. As in the other forms of cerebral syphilis, headache is a prominent prodromal symptom. In not a few cases the headache is attended with localized tenderness on percussion of the skull. The most significant symptom of this form of disease is cortical or Jacksonian epilepsy. This symptom may begin with a sensory aura in the arm, leg, face, or tongue, which is soon followed by muscular twitchings. At the outset the convulsions are limited to one side of the body and for a considerable period may involve only one or more groups of muscles. But after they have lasted for a variable period they may become much more general and finally may extend over the entire body. As a rule, it is found that the convulsion spreads in a definite manner from one group of muscles to another, and that the mode of progression remains the same in subsequent attacks. Consciousness is often retained throughout the seizure, though it is generally lost when the convulsion extends to both sides of the body. After each attack slight paralysis may develop temporarily in the affected parts. It grows most pronounced after repeated attacks and finally may remain permanent. The convulsions sometimes recur with such frequency that the status epilepticus develops. In not a few cases this condition is the immediate forerunner of death.

Like other cerebral symptoms of syphilis, cortical epilepsy and paralysis may disappear suddenly and may remain absent for many months, even without antisyphilitic treatment.

The monoplegias due to meningitis of the convexity sometimes develop prior to the epileptic attacks. Furthermore, the monoplegia may be converted suddenly into hemiplegia on account of extension of softening downward into the white matter of the hemispheres.

The symptoms described above are due to localization of the lesion in the motor zone. Meningitis of other parts of the cortex will produce symptoms corresponding to the functions of those parts. The most frequent symptoms are aphasia and hemianopsia. The aphasia is often ephemeral in character and may even last only a few minutes at a time It is apt to be attended or preceded by convulsive twitchings on the right side of the body, starting usually from the muscles of the face and tongue. After a variable period the aphasia usually becomes permanent.

Hemianopsia, due to an affection of the occipital lobes, is not very rare. This symptom is apt to be attended by visual hallucinations, which are referred to the blind side of the field of vision. When the meningitis is more diffuse and extends over a considerable part of the convexity of one or both sides, mental disturbances may be the chief feature in the clinical history. In such cases the first symptom noticeable may be a change in the character of the patient, who becomes morose, peevish, irritable, loses judgment in business affairs and exhibits decided lapses of memory. There may be a pronounced melancholy tinge at an early stage. In rarer cases, maniacal attacks, sometimes attended with destructiveness, are observed very early. Ideas of grandeur may be noticed at times, but, as a rule, they are not very persistent or well defined, and they do not last as long as in general paresis. Headache may be a prominent symptom and usually exhibits the well-known syphilitic characteristics. Speech sometimes becomes slow and labored, and there may even be tremor of the tongue and twitchings of the lower facial muscles. The dominant symptom, however, is the mental failure, which usually progresses more or less rapidly, but sometimes shows very pronounced remissions. Paralysis of various cerebral nerves is quite common, likewise sudden attacks of temporary aphasia. Convulsive or apoplectiform seizures are also frequently observed and serve to increase the resemblance to general paralysis of the insane. Indeed, the latter disease is found in such an immense proportion of cases among syphilitic subjects that it may be difficult or even impossible to distinguish it from cerebral syphilis.

Gummy tumors, when solitary and uncomplicated with other lesions of the brain or vessels, present the same clinical history as do other varieties of tumor, except that exacerbations and remissions of the symptoms are much more frequent in the former (*vide Brain, Tumors of*, in the present volume). In addition, choked disc is comparatively rare in gummata, while it is a frequent attendant of other varieties of tumor.

DIAGNOSIS.—Of course, the first element in diagnosis is the recognition of previous infection with syphilis. In many cases this is a very simple matter, but in numerous instances the symptoms at the time of the original infection were so slight, and such a long interval has elapsed before the outbreak of cerebral symptoms, that it may be extremely difficult to make a positive diagnosis. Moreover, in negative cases we must not forget that many patients attempt to deceive the physician in regard to the contraction of venereal disease. In doubtful cases careful search must be made throughout the entire body for any traces which may have been left over by the original disease.

Headache is an important sign at the beginning of cerebral syphilis, in whatever part of the brain tissues the lesion may be located. The pain exhibits the characteristics described in the previous section, but it must be remembered that the nocturnal exacerbations are sometimes absent.

The occurrence of cortical epilepsy in a syphilitic subject is also very significant. It must not be forgotten that this may start with either convulsions or paralysis, although the former are a much more frequent initial symptom. Unlike ordinary epileptic attacks, these seizures are often unattended with unconsciousness.

Another important sign of cerebral syphilis is the heterogeneous character of the symptoms (paralysis of the cranial nerves, hemiplegia, aphasia, convulsions, etc.), a fact which is naturally due to the varied character of the lesions present in the brain. In many cases the secondary manifestations of the constitutional disease are very slightly marked, so that they may have been unnoticed by the patient, and, as the initial lesion is often disregarded, he may be unaware of his infection with the specific virus. But so significant are the heterogeneity and anomalous distribution of the symptoms that the existence of syphilis should be suspected in every case of nervous disease in which the symptoms appear to be due to an organic affection but are grouped in an irregular and anomalous manner. Buzzard says: "I should not take much account of this absence [of syphilitic symptoms], if there were other reasons for strongly suspecting syphilis, for we are continually meeting with cases in which the symptoms caused by lesion of some part of the nervous system constitute of themselves the only testimony to the specific nature of the disorder, and experience shows these to be quite as pathognomonic as affections of the skin." The brilliant results which are often obtained by vigorous antisyphilitic treatment may also prove a valuable aid in diagnosis. It is true that, in rare cases, very favorable results are also obtained by such treatment in non-specific cases, but we can hardly expect such pronounced changes as are seen in syphilitic affections.

Another very important characteristic of the symptoms of cerebral syphilis is their remarkable changeableness. For example, an attack of aphasia may last only a few minutes or hours, or an attack of hemiplegia may disappear within a day or two. In no other disease, with the exception of hysteria, is this ebb and flow of the symptoms noticed in such a marked degree.

In making a diagnosis of syphilis of the cerebral vessels, as distinguished from other syphilitic lesions of the brain, special stress should be laid upon the absence of irritative symptoms. The localization of the lesion in the individual arteries will depend upon the same factors as in ordinary cerebral embolism and thrombosis. The problem is frequently complicated, however, by the coincident affection of several vessels, and perhaps by the existence of other syphilitic lesions.

The diagnosis of gummy basilar meningitis is based chiefly on the prominence of paralyses of various cerebral nerves, in addition to the other evidences of cerebral syphilis. It should be borne in mind, however, that in rare cases the syphilitic lesion appears to be confined to the cerebral nerves themselves (multiple neuritis). In basilar meningitis, however, the cerebral-nerve paralyses are complicated sooner or later by other symptoms, such as hemiplegia, hemianæsthesia, etc.

The most significant symptom of meningitis of the convexity is the development of cortical epilepsy. Hemianopsia, attended by visual hallucinations, is also a very characteristic symptom. The occurrence of temporary aphasia is also apt to be the result of syphilitic lesions of the convexity. In addition to these special focal symptoms, we usually find the general symptoms which have been described in the section on Symptomatology.

When the syphilitic changes in the brain are very diffuse, especially when they involve a large part of the convexity of one or both hemispheres, mental symptoms are often prominent, and it may be difficult to distinguish the condition from dementia paralytica. The latter affection runs a progressive course and ends fatally in a few years. In cases of cerebral syphilis proper treatment may result in very marked improvement and occasionally in recovery. Inequality of the pupils is much more common in dementia paralytica, but in rare cases of cerebral syphilis pupillary changes are found for years before the outbreak of other symptoms. In cerebral syphilis the focal symptoms are prominent and the dementia, while it is more stable in character, does not lead gradually to complete dementia. True ideas of grandeur are comparatively rare in syphilitic dementia, and are frequent in dementia paralytica. On the whole the evidences of an organic disease of the brain are much more decided in cases of cerebral syphilis than in dementia paralytica.

Prognosis.—However mild the symptoms of cerebral syphilis may be at the outset of the disease, the prognosis is always serious. It is true that a considerable proportion of cases recover, but the danger of relapse is always to be kept in mind. There seems to be some ground for believing that when the original syphilitic infection runs a mild course, subsequent cerebral manifestations are apt to be severe in character. This may be owing to the fact that antisyphilitic treatment is not carried out very vigorously or persistently unless the symptoms are severe. Nungazzini, on the other hand, claims that malignity of the morbid process and early death are characteristic of many cases of early syphilis of the brain.

Contrary to the opinion of many writers, we have not found that the general condition of the patient has much effect upon the course of the disease, except in those cases in which there is excessive indulgence in alcoholic stimulants.

Among the various forms of cerebral syphilis the most unfavorable prognosis is presented by lesions of the blood-vessels. Even a lesion which is very slight in actual dimensions may be sufficient to interfere very seriously with the circulation in the brain. When a vessel is occluded entirely, softening in its area of distribution develops very rapidly and the function of such parts is never restored. The most serious results are observed when the basilar artery is the site of disease.

The most favorable results are seen in gummy tumors and gummy meningitis of the convexity. Symptoms which point very conclusively to gummy tumors may disappear completely under treatment. Gummy meningitis of the convexity also promises a more favorable prognosis than other localizations, but in these cases recovery is usually incomplete. This is particularly true of cases in which mental disturbances have been prominent.

Gummy meningitis at the base of the brain presents almost as unfavorable a prognosis as syphilis of the vessels, and indeed the two conditions are very apt to be associated. In many cases, however, the extent and rapidity of the improvement secured by antisyphilitic treatment are little less than marvellous.

Treatment.—The treatment consists practically of the administration of antisyphilitic remedies, and the earlier we resort to these remedies the more assured is a successful result. Hence the extreme importance of an early diagnosis and the advisability of specific treatment in all doubtful cases.

In our hands more benefit has been derived from the use of potassium iodide than from the preparations of mercury; but this opinion is not held by all writers. German authorities in particular usually lay more stress upon the exhibition of mercurial preparations.

Unless the patient manifests an idiosyncrasy with regard to one or the other of these drugs, the mixed treatment should always be adopted. The dosage should depend solely upon the tolerance of the patient. In some cases the effect desired is not secured until enormous doses (an ounce or even more) of potassium iodide are given in the course of twenty-four hours. The notion is quite prevalent that such large doses are dangerous to the general condition of the patient, but this opinion is not justified by our own observation. For internal administration we usually rely upon bichloride of mercury, beginning with one-thirty-second of a grain, and increasing rapidly until the desired effect is obtained. The mercury is given in solution with potassium iodide, the initial dose of the latter being usually fifteen grains, unless the symptoms are very urgent, when much larger doses may be given at once. This mixture is best given about two hours after meals and should always be largely diluted (one-half to one tumblerful of water, Vichy water, or milk). If we wish to increase the dose of the two drugs at varying rates, it is preferable to give the mercury in the shape of tablets. Sometimes it is necessary to give daily as much as one-eighth of a grain or even more, according to the indications in the individual case. It is a good plan to keep on increasing the dose until the gums become a little tender, and then an amount slightly smaller than that necessary to produce such an effect may be continued for a long time. In grave cases, when we wish to overwhelm the patient with the drug, it is better to use inunctions of mercurial ointment regardless of its effect upon the gums. If the patient is unconscious, my plan has been to administer the mercury by inunction and the iodide of potassium by rectal injections. As much as from 4 to 6 gm. of the iodide (diluted with water or milk) may be injected every four hours. When the patient recovers consciousness, the drug may again be administered in the usual way.

During the entire period of treatment, the patient should devote extreme attention to the care of the teeth and mouth. The teeth should be very carefully brushed after each meal, and the mouth rinsed several times a day with a weak solution of listerine or some other mild antiseptic.

After serious symptoms have subsided, the dose of the antisyphilitic is gradually diminished to a certain extent, but should be continued persistently (if possible, without intermission) for at least one or two years after the disappearance of all evidences of the disease.

I cannot express myself too strongly concerning the extreme importance of protracted treatment and the necessity of administering the remedies in sufficiently large doses. The dose is to be regulated solely by the amount requisite to control the symptoms in each individual case.

Apart from the use of the strictly antisyphilitic remedies, very little can be done in the way of treatment. When the pains do not yield to these drugs, opium must be resorted to, and perhaps the repeated application of blisters to the back of the neck will prove useful. Repeated convulsions are sometimes controlled by the addition of bromide of potassium to the iodide mixture. The patients should be strictly warned against the use of alcoholic stimulants in any shape, and also against indulgence in sexual intercourse. They should be kept as free as possible from excitement and overwork, and regular, easy evacuations of the bowels should be secured daily.

Leopold Putzel.

BRAIN: TRAUMATIC AFFECTIONS. See *Skull, Diseases and Injuries of.*

BRAIN: TUBERCULOUS MENINGITIS.—(Synonyms: Acute Hydrocephalus, Granular Meningitis, Basilar Meningitis, Dropsy of the Brain.)

Definition.—Tuberculous meningitis is an acute inflammation of the pia mater of the brain, due to infection by tubercle bacilli, and characterized by the deposit of miliary tubercles and an effusion of pus and lymph.

General Observations.—In 1768 the attention of the profession was first particularly called to this disease by Dr. Robert Whytt, of Edinburgh. His remarkable monograph, entitled "Observations on the Dropsy of the Brain," ranks to-day among the medical classics, and is highly commended by all recent writers for its accuracy of description and fulness of detail.

Dr. Whytt, and the observers immediately succeeding him, framing their opinion as to the nature of the affection from the very prominent anatomical lesion—the ventricular effusion—unavoidably included, under the term *dropsy of the brain*, several other diseases besides tuberculous inflammation of the meninges. No correct idea of its pathology could be attained until Göelis, in 1815, pointed out that acute ventricular dropsy was not a primary condition, but was always dependent upon some antecedent affection of the cerebral vessels or nerves.

Although the granular condition of the meninges had been previously noted by Guersant, it was reserved for Papavoine, in 1830, to establish the tuberculous nature of these granules, and to point out their pathological relation to the meningeal inflammation.

The name of tuberculous meningitis, which has won its way to universal acceptance, was suggested by Bricheteau. Dr. Gerhard, of Philadelphia, was the first to call attention to the disease in this country. His most valuable paper, published in the *American Journal of the Medical Sciences* (1833-34), was based upon the reports of thirty-two cases, with autopsies (Minot).

Tuberculous meningitis is not an independent affection, but is one of the most important phases of that protean malady, acute miliary tuberculosis. It rarely, if ever, occurs as the sole tuberculous lesion in the body.

Two forms of the disease are recognized, a primary and a secondary form. In the former, although other organs besides the pia may be the seat of tubercles, the symptoms first noticed are those arising from the cerebral lesion, and these retain their prominence throughout the attack. In the secondary form, on the other hand, the brain symptoms are preceded by those arising from inflammatory affections of other viscera, also dependent upon the diathetic influence, and are only manifested toward the close of the illness.

Tuberculous meningitis is one of the most important and most fatal organic diseases of the cerebro-spinal system. The primary form is essentially a disease of early life, and occurs with special frequency between the ages of two and ten years. Infancy and adolescence do not confer entire immunity, but at these periods of life the disease is almost always secondary to advanced pulmonary tuberculosis. Statistics indicate that males are more susceptible to the disease than females; according to Huguenin, this preponderance is much oftener observed in children under fifteen years of age than in adults.

Etiology.—The essential factor in the causation of tuberculous meningitis is the infection of the pia mater with tubercle bacilli. They may reach the brain through the lymphatics or blood-vessels. Foremost among the predisposing causes must be placed the hereditary diathesis. The badly nourished and physically ill-developed children of consumptive parents are the most susceptible, but the apparently rugged and robust are not exempt; in the latter, however, a careful search will almost certainly disclose a taint in some collateral branch of the family, if not in the direct line of descent.

That the disease is with rare exceptions dependent upon foci of caseous degeneration in some remote gland or viscus, a suppurating joint, or tuberculous inflammation of bone, is now generally recognized by modern pathologists. Seitz found such lesions in more than ninety-three per cent. of the cases tabulated by him. Holt states that "although it is not infrequent to see meningitis without symptoms of tuberculosis elsewhere, I have never failed at autopsy to find other tuberculous lesions in the body."

The exciting causes are obscure. Unpropitious external conditions of all kinds, such as impure air, unwholesome food, exposure, bad drainage, may kindle into activity a slumbering predisposition.

Blows upon the head, emotional excitement, exposure to the direct rays of the sun, and like causes exert a doubtful influence. Climate and seasons have no place among the etiological factors, although the disease is more prevalent in the changeable weather of winter and spring.

It is not improbable that, in older children, excessive study and worry, or the high-pressure system of modern schools, may promote the disease in those predisposed by inheritance to tuberculous affections; and, in this connection, it may be stated that such children are, as a rule, precocious and ambitious to excel in their studies.

Morbid Anatomy.—The distinctive anatomical feature of tuberculous meningitis is a deposit of miliary tubercles in the pia mater of the brain. These granules are always found on the inner surface of the membrane, are grayish white, semi-transparent, and vary in size from an object just visible to the naked eye to that of a millet or hemp seed. "These are really the seats of activity of the bacilli" (Lloyd). The coalescence of several nodules may form tubercular masses as large as, or larger than, a pea. They are usually more numerous at the base, especially about the fissure of Sylvius and the optic chiasm, but in rare instances are formed in greater numbers on the convexity. The distribution is generally symmetrical in the two hemispheres, but may be limited to any particular portion, even to the narrow area fed by the branches of a single artery. They are always developed within the perivascular canals, and adhere to the coats of the arteries, giving somewhat the appearance of a string of beads. They may be few in number or so abundant as to impair the integrity of the coats of the vessels and completely obstruct the circulation.

Hektoen found tubercles in the intima, accompanied by extensive endarteritis. His investigations showed the intravascular lesion to be primary, due to the implantation upon the intima of bacilli from the blood. The number of the nodules does not determine the intensity of the inflammation, which may be slight in the presence of a large deposit, or severe with a few widely scattered granules.

The pia mater is thickened, opaque in appearance, more or less adherent to the surface of the brain, and often is studded with tubercles.

Other changes may be noted which are to a certain extent common to all forms of meningeal inflammation. A sero-purulent exudation covers the pia, especially at the base, and extends along the course of the arteries. It may be so copious as to embed the cranial nerves and fill up the natural depressions at the base of the brain.

The ventricles are almost invariably distended with fluid. The effusion into the ventricles, which was considered by the early authors to be the essential anatomical lesion, furnishes the most common name for the disease. It varies largely in quantity, but is generally sufficient to distend the ventricles, flatten the convolutions, and render them dry and anæmic. There is often bulging of the fontanel and sometimes even separation of the sutures when they are not completely ossified. The fluid has a specific gravity of about 1.010, is usually turbid from the admixture of epithelium and leucocytes, and is sometimes, though rarely, tinged with blood. The portions of the brain adjacent to the ventricles are softened. The fornix and septum lucidum may be almost diffluent, and the basal ganglia so altered in consistence as to fall into a shapeless pulp on being removed from the skull (Fagge).

The choroid plexuses are hyperæmic, and sometimes covered with purulent exudation. The convolutions are œdematous and injected when the ventricular effusion is small or wanting, but are dry, bloodless, and flattened when the effusion is large. Occasionally patches of red softening, punctiform hemorrhages, and, very rarely, large extravasations of blood are met with in the substance of the brain.

Changes similar in kind to those above described, but less in degree, are sometimes found in the spinal cord and its membranes.

In tuberculous meningitis the lesions are very rarely limited to the intracranial viscera. Tuberculous deposits almost invariably occur in other organs of the body, most frequently in the lungs; or there are remote depots of caseating material or other evidences of the cachexia. Tubercles can often be demonstrated by means of the ophthalmoscope in the choroid coat of the eye. Dr. Money found the choroid affected in fourteen out of forty-two cases of tuberculous meningitis. In one instance tubercles were observed in the eye, but not in the brain or its membranes; in another, the meninges were free, but there was a mass of crude tubercles in the cerebellum (London *Lancet*, 1883). According to Oliver tuberculous meningitis is more prone than other forms of meningitis to cause changes in the optic nerves.

SYMPTOMS.—Tuberculous meningitis is nearly always preceded by premonitory symptoms which, if rightly interpreted, are of the highest value. In twenty-six cases collected by Dr. Gee there were only two in which prodromes were absent. These symptoms are usually so indefinite in character as to excite little attention at the time, and are rarely thoroughly appreciated until the developed disease leads the parents carefully to review the past weeks of the child's life.

This period probably corresponds with the deposit of miliary tubercles in the pia mater before serious structural changes have taken place.

The symptoms met with during the prodromal stage relate chiefly to the nutritive and digestive processes. The appetite is capricious, the breath offensive, and the tongue furred. Vomiting is not common. The bowels are slightly constipated, or diarrhœa and constipation alternate. The child tires easily and will often be found asleep on the floor surrounded by his playmates and toys. At night, sleep is restless and disturbed by dreams. Headache is not a prominent symptom, but is rarely wholly absent. Frequent complaints of dizziness are made. Very rarely double vision is observed. Along with these symptoms will be noted an alteration in the child's character. This is one of the most important of the prodromes, and should never be overlooked in endeavoring to make a diagnosis in a doubtful case. The patient, before precocious and vivacious, becomes dull and listless, indifferent to his books or plays, moody, and petulant. Many grow very emotional, bursting into tears on the slightest provocation, or dispensing their caresses with annoying lavishness. Before the close of the prodromal period the effect of imperfect nutrition is apparent. The patient grows thinner and paler. The muscles become soft and flabby, and he is day by day less inclined to exertion of any kind. The prodromal stage may last for from one week to three months.

It is customary, for convenience of description, to divide the disease into distinct stages, based upon the predominance of certain symptoms at different periods in its course, viz., a stage of *invasion*, one of *pressure*, and one of *paralysis*. This arrangement is purely arbitrary, and is rarely fully justified by clinical observation.

There are few diseases more irregular in the development or sequence of symptoms than tuberculous meningitis, and he who seeks at the bedside only the typical case of the books may long search in vain.

Since the age of the patient impresses some minor differences upon its course, we will first describe the disease as seen in children.

Stage of Invasion.—The onset is rarely announced by any sudden perturbation, like a chill or convulsion, but usually the symptoms of the prodromal stage are increased in severity and gradually reinforced by others characteristic of cerebral lesions.

Headache, vomiting, and fever are the common initial symptoms. Of these, vomiting is perhaps the most constant. It varies greatly in frequency, is not usually troublesome after the first few days, though it may continue during the entire illness, and seldom returns, after it has once ceased for twenty-four hours. It is especially provoked by the ingestion of food or drink, and by rising in bed, and, as a rule, is not preceded by nausea or accompanied with severe retching.

The headache is intense, and constitutes one of the most distressing features of the disease. It is usually referred to the frontal region. The pain is aggravated by sudden movement, bright light, or loud noises, and is subject to exacerbations without apparent cause. It at times compels the child to make outcries, hold his head with his hands, or bury his face in the pillow. Fortunately, remissions of variable duration are not infrequent. Vertigo is occasionally present, manifested by unsteadiness of gait, or a sensation of falling, even when lying in bed. The complaint of headache in a child, especially when associated with vomiting, should always awaken the gravest apprehensions.

There is no distinctive temperature curve. The fever is moderate in intensity, irregularly remittent in type, and rarely measures more than 103° F. in the evening, and 100° F. or 99° F. in the morning. Constipation is very constant. It is usually marked from the beginning of the illness, and is rebellious to the action of laxatives; yet cases are recorded in which persistent diarrhœa has occurred without tuberculous or other disease of the gastro-intestinal mucous membrane (Huguenin). Anorexia and moderate thirst are present. The tongue may be clean, but is generally heavily coated.

The pulse for the first few days is rapid and regular, but soon becomes slow, irregular, and variable. The variability is marked; the slightest exertion or excitement will cause an increase of twenty or more beats per minute, and a like effect may be often produced without known cause.

The respiration is changed in like manner, and after three or four days becomes irregular and sighing. These alterations in the pulse and breathing are by no means constant in the early stages. They may be marked at one, and absent at several subsequent visits; in fact, fluctuations may be noted in the course of the same observation. Repeated and lengthy examinations must therefore be made before they are declared absent. It is important to make the examination of the pulse when the child is at rest, since a pulse which is slow and irregular during repose may be rapid and regular under excitement or after movement.

Sleep is fitful and disturbed. Mild delirium is observed at some period of the day or night. The pupils are contracted, and light is painful to the eyes.

During the early part of this stage, both special and general sensibility are increased, so that the child often receives with dread even the gentle ministrations of its mother. Later on, he becomes more passive, and will without a murmur submit to the protracted examination of the physician.

If the cranial bones are unossified, the anterior fontanel is distended.

Strabismus, double vision, and ptosis sometimes appear toward the end of the stage of invasion. Convulsions are not common, but muscular twitchings and rigidity of the muscles of the spine are occasionally noted.

The child is dull, apathetic, and drowsy from the beginning. At first he can be easily aroused, and although his mental operations are sluggish, he notices his surroundings and may at times amuse himself with his playthings. The somnolence gradually increases until, toward the close of this period, he will, if undisturbed, lie for hours in a deep sleep, with eyelids half-open, grinding his teeth, and at times uttering a sharp, piercing shriek—*the hydrencephalic cry* of Coindet. Some authors place great stress upon this cry, but Rilliet, Gee, and others hold that it is not special to nor frequent in tuberculous meningitis.

The duration of this stage is from seven to fourteen days.

Stage of Pressure.—The signs of irritation now give place to those of pressure or exudation upon the surface of the pia and into the ventricles of the brain. The transition takes place gradually; in fact, there is usually a period of uncertain duration, which has been not inaptly named the *mixed stage*, in which the "symptoms of irritation still linger and the symptoms of depression are just manifesting themselves" (Bartholow).

Paroxysms of pain, great restlessness, irritability, and delirium are succeeded by periods of extreme drowsiness or even of profound stupor, out of which the child is aroused with difficulty, perhaps replies in monosyllables, or stares vacantly at the questioner through half-open lids, and again lapses into his former condition.

The most characteristic feature of this stage when fully developed is loss of consciousness. The patient remains in a state of complete insensibility, and at times moans or shrieks out wildly. He commonly lies on one side, with the knees drawn close to the abdomen, one hand pressing his head and the other grasping the genitals.

The head is often retracted, and the muscles of the nape of the neck are rigid. The pulse becomes slow—from 40 to 80 beats in the minute. The irregularity of the pulse and respiration are more pronounced and more constant than before. Typical Cheyne-Stokes respiration is often observed. The temperature falls a degree or more and often becomes subnormal. Vomiting ceases, if it has not already done so, but constipation persists. The abdomen is deeply hollowed. The common term "boat-shaped" very accurately describes the sunken belly bounded by the unduly prominent symphysis, iliac crests, and ensiform cartilage.

The pupils are dilated, often unequally, and sometimes waver under light. The globe rolls from side to side, the sclerotic is suffused, a puriform secretion collects in the angles of the eyes or glues together the edges of the lids. The ophthalmoscope shows ischæmia of the optic discs or beginning neuro-retinitis. In rare instances, miliary tubercles are seen in the choroid. Dr. Allbutt found retinal lesions in twenty-nine out of thirty-eight cases of tuberculous meningitis.

The skin presents peculiar vaso-motor disturbances. Small patches or spots of congestion appear on the cheeks, forehead, or ears, and quickly fade away, their bright color making a vivid contrast with the general pallor. If the finger-nail be lightly drawn across the abdomen or inner surface of the thigh, a bright-red line comes out slowly, persists for a few moments, and then gradually fades—the *tâche cérébrale* of Trousseau.

Paralyses, both local and general, are commonly met with at this period; as are also rigidity or pendulum-like movements of one or more of the extremities.

The contents of the bladder and rectum are usually discharged involuntarily.

Stage of Paralysis.—From twenty-four to forty-eight hours before death, some of the characteristic symptoms undergo a remarkable alteration. The period covered by these changes is known as the stage of paralysis. The child now lies completely comatose and irresponsive to external irritations. Only reflex movements can be excited, and these imperfectly.

The constipation which has marked the whole progress of the illness is now often replaced by copious, involuntary, liquid stools; the sunken abdomen becomes distended with gas; the slow pulse becomes rapid and feeble, numbering 160 to 180 beats per minute, and the mercury registers a temperature of 104° to 107° F. This second rise in pulse and temperature is a certain forerunner of speedy dissolution.

The capillary circulation is more and more interfered with, the respirations become less distinct, and death may occur quietly in deep coma or be ushered in by a convulsion. Death by coma is the more common mode.

Sometimes the death agony is prolonged for several days, to the great grief of the parents. Death occurs in from sixteen to twenty-one days after the appearance of the initial symptoms.

TUBERCULOUS MENINGITIS IN THE ADULT.—The course of tuberculous meningitis in adults varies sufficiently from that observed in children to deserve brief mention.

The disease is more common in men than in women, and occurs at all ages, but especially between the years of seventeen and thirty. It is almost invariably secondary to advanced tuberculous disease in some remote part, the symptoms of which to a certain extent mask those of the meningeal affection. The primary form of the disease is rarely met with in adult life.

Premonitory symptoms are usually absent, and when present never obtain the same prominence as in early life. Persistent vomiting and convulsions rarely usher in the attack, but local paralyses, hemiplegia, and aphasia—very seldom seen in childhood—are not infrequently the first symptoms to direct attention to the cerebral complication.

The disease ordinarily runs a much shorter course than in children. Death may occur within forty-eight hours after the appearance of brain symptoms, and is seldom delayed longer than fourteen days.

DIAGNOSIS.—The diagnosis of typical, fully developed tuberculous meningitis can scarcely give serious trouble, but in the prodromal period, or in those cases which pursue an irregular course or in which some of the prominent symptoms are absent altogether, it is proverbially difficult.

Since the disease is almost invariably engrafted upon a tuberculous diathesis, a careful investigation of the family record and personal history should be at once instituted. It is, however, only by the exercise of the most painstaking care, by closely observing the physiognomy and actions of the child, and by noting the hourly variations in the symptoms, that an early diagnosis can be reached in doubtful cases. Ill-defined ailing in a scrofulous child which resists ordinary treatment, especially if accompanied with headache and causeless vomiting, should always awaken suspicion.

The diseases for which tuberculous meningitis is most liable to be mistaken are acute simple meningitis, hydrencephaloid disease, gastro-intestinal disturbances, and typhoid fever.

Simple meningitis is ordinarily recognized by the sharper onset (without prodromes), more severe headache, more furious delirium, higher temperature—in short, the greater intensity of all the symptoms and its rapid course. The comparative rarity of the simple over the tuberculous form of the disease should be remembered. In exceptional cases the differentiation cannot be made.

False hydrocephalus is usually readily known by the history of antecedent diarrhœa or other exhausting malady, the prostration when the cerebral symptoms began, the rapid and feeble pulse, the depressed fontanel, the pallor, and the normal or even subnormal temperature. All authors speak of the resemblance which certain cases of typhoid fever bear to the disease under discussion. The infrequency of typhoid fever in patients of the age most prone to tuberculous meningitis, the regular temperature curve, the diarrhœa, the iliac gurgling, the rose-colored spots, and the splenic tumor will generally easily establish the nature of the disease.

The subacute gastro-intestinal disturbances to which children, especially cachectic children, are so liable may lead to error. Feverishness, anorexia, vomiting, irritability, and headache are common to each, and in many cases the development of the symptoms must be awaited to clear up the diagnosis.

The more intense headache, the irregular pulse, the sighing respiration, the alterations in the pupils, and the graver aspect of the illness will generally speedily indicate its cerebral nature.

The lumbar puncture of Quincke sometimes gives valuable information. It is especially valuable in the differentiation of meningitis from other diseases accompanied by marked brain symptoms.

The discovery of tubercle bacilli in the spinal fluid is positive evidence of the nature of the disease. They are, however, difficult of demonstration, and are not always present in undoubted cases of meningeal tuberculosis.

Fürbringer found bacilli in thirty out of thirty-seven examinations.

The changes which take place in the fundus of the eye are often among the early signs of meningeal inflammation, and hence are valuable in diagnosis. However, too much reliance must not be put upon the ophthalmoscopic examination. Dr. Fagge remarks: "The clinical value of ophthalmoscopic changes in the optic discs is still somewhat doubtful. It is certain that a normal state of the retinæ is no proof of the absence of tuberculous meningitis, but I believe the time has not yet arrived for a dogmatic expression of opinion as to the positive significance of ischæmia (or even of retinitis) as between that disease and some less severe affection of the brain, such as might be attended with great vascular congestion of its tissue. One appearance indeed is conclusive, namely, the presence of tubercles in the choroid. It is true that they belong not to the meningeal affection itself, but rather to a general acute tuberculosis, but this fact in no degree diminishes their diagnostic importance" ("Practice of Medicine"). Dr. Minot says on this point that "choroidal tubercles are so rarely seen as to be of little avail in diagnosis. In fact, they are less frequent in this disease than in general tuberculosis without meningitis. In twenty-six cases of tuberculous meningitis examined by Garlick at the London Hospital for Sick Children they were found only once" (Pepper's "System of Medicine").

Dr. Bastian (Quain's "Dictionary of Medicine") places great reliance upon the microscopic examination of the blood in the diagnosis of tuberculous meningitis. He mentions the following alterations in the blood as peculiar to this affection: an increase in the number and exalted amœboid activity of the white corpuscles; groups of protoplasmic particles of various sizes interspersed among the blood corpuscles, as well as here and there small pigment granules. The red corpuscles tend to run together into irregular masses rather than into definite rouleaux, but present no distinctive changes.

Prognosis.—The prognosis is absolutely bad. When fully developed, tuberculous meningitis almost invariably marches steadily on to a fatal termination. Delusive lulls not infrequently occur, however, even in the advanced stages, when an unwary practitioner may doubt his diagnosis and raise hopes in the parents which are doomed to bitter disappointment.

The possibility of recovery from the early stages of the disease cannot now be successfully denied, although it is not, perhaps, uncharitable to doubt the correctness of the diagnosis in many of the recorded recoveries. Rilliet, Rousseau, and other equally eminent clinicians report cases in which death occurred from a relapse some time after recovery from the first attack; and at the autopsy, old and recent tubercles of the pia could be clearly distinguished. Huguenin does not even accept the revelations of the post-mortem examination as conclusive, and remarks that "pathological anatomy furnishes no information the correctness of which it would not be possible to doubt."

The isolated exceptions who do survive an attack of tuberculous meningitis are nearly always left with impaired mental or physical powers, and sooner or later succumb to a recurrence of the disease.

The writer has seen recovery in one case which was well advanced in the second stage, and in which there could scarcely be a doubt as to the tuberculous nature of the disease; but the patient never fully regained his mental faculties, and died in convulsions eighteen months afterward.

Treatment.—Tuberculous meningitis is so universally fatal that but little benefit can be hoped for from the administration of remedies. There are no drugs that can control or retard the specific action of the tubercle bacilli on the membranes of the brain. The treatment is wholly symptomatic and palliative. Treatment should not, however, be abandoned too soon, as a positive diagnosis between the simple and the tuberculous form of meningitis is not always possible in the early stages.

In the present stage of our knowledge, the greatest good must come from the adoption of measures to prevent the development of the cachexia in those so predisposed. It is not necessary for us to detail here the special means to be employed; they are set forth at length in other chapters of this Handbook.

In general terms, however, we may say that, in the presence of the diathesis every influence which tends to develop the nervous system at the expense of the digestive and muscular systems will increase the liability to the disease.

The violent antiphlogistic measures formerly employed in the treatment are now properly discarded. As soon as the nature of the disease is known or strongly suspected, the patient should be placed in a darkened room and all sources of cerebral excitement excluded. An active calomel purge should be at once administered. An ice-cap must be applied to the head and upper portion of the spine and warm applications to the extremities.

Special symptoms must be met as they arise by the use of the customary remedies, but our chief reliance in arresting the disease lies in the use of the bromide and iodide of potash. The bromide may be omitted during the pressure stage, unless convulsions ensue, but the iodide must be given until treatment is abandoned.

Sometimes, during the stage of excitement, opium may be advantageously combined with the bromide. Flattering reports have been published from the use of iodoform inunctions, and a Swedish physician, Dr. Warfvinge, reports five successful cases. The method followed by Dr. Warfvinge consists in shaving the head and anointing it with an ointment consisting of iodoform, 1 gm., in vaseline, 5 gm. This is applied twice daily, the head being afterward covered with an impermeable cap. This method has still a few advocates, but it never gained the confidence of the profession and is practically abandoned. Lumbar puncture has been recently practised in a large number of cases, both as a curative and as a diagnostic measure, but the later reports are not such as to commend the practice. Rotch and Wentworth report alarming symptoms following its use in a two-year-old child. *W. J. Conklin.*

BRAIN, TUMORS OF THE.—The symptoms caused by tumors of the brain are due, first, to irritation or destruction of the portions of the nerve tissue in which they are embedded, or near to which they lie; second, to pressure exercised upon the entire contents of the cranium—nerve tissue, blood-vessels, and lymphatics. The first class of symptoms are common to tumor, and to all other circumscribed lesions of the same locality, thus especially patches of chronic softening. The second class are common to all conditions in which the intracranial space is encroached upon; such are extra- as well as intra-cerebral tumors, morbid products within the brain, which differ considerably from neoplasms proper, and finally, abscesses and aneurisms. Thus, the investigation of the case of any patient exhibiting cerebral symptoms demands that we decide: first, whether these are caused by a new growth of any kind, which is encroaching upon the cranial cavity; second, this being admitted, what is the nature of the growth; third, what is its precise locality.

The prognosis must then be framed according to the fact, the nature, and the seat of the growth; and, finally, the (very limited) indications for treatment must be considered.

Symptoms Indicating the Existence of an Intracranial Growth.—These are of two kinds: those belonging to the perversion or abolition of cerebral function, and those indicating a rise of intracranial pressure. The first are the focal, the second the diffused symptoms (Griesinger). It is this second class of symptoms which are of the most importance in distinguishing between tumor and other cerebral lesions, and they may therefore be considered first.

Diffused Symptoms.—These are headache, vertigo, vomiting, general epileptiform convulsions, apoplectiform attacks, psychic disturbances, and choked disc.

Headache is one of the earliest and most constant symptoms of intracranial tumor. The intensity of the pain is usually severe, has even led to suicide, but this very intensity may sometimes confuse the diagnosis with hemicrania. From this functional disease it is sufficiently distinguished by its persistence. It may, for some time, precede all other symptoms of tumor. Although it is on the whole persistent, there may, in a certain number of cases, be intervals of freedom of several hours, days, weeks, or even months in duration. Not unfrequently is the headache periodic, and it may then be mistaken for an apyretic malarial attack. Frontal headache may simulate brow ague, or occipital headache the cervico-occipital neuralgia of gout. The pain is apt to be exacerbated at night, or to grow worse in the early morning hours, a fact probably due to stagnation of the intracranial lymph stream determined by the lowered blood pressure during sleep. The pain is also increased by every condition liable to cause congestion of the head; thus by psychical excitement, alcohol, straining at stool. The headache may be diffuse or localized, but the localization of the pain does not assist much in the localizing diagnosis of the tumor. Frontal tumors frequently excite occipital headache. Although so prominent a symptom when it exists, headache is by no means always present. It was absent in 148 out of 274 cases analyzed by Ball and Krishaber. By combining the tables of Ladame and of Bernhardt (the first summing up all cases published earlier than 1868, the second those between that date and 1880), we can construct the following table, showing the proportion of cases of headache with cerebral tumors of different localities:

TABLE I.

Seat.	Number of cases.	Number with headache.	Per cent.
Cerebral peduncle	10	4	40
Basal ganglia	41	19	48
Cortex.........................	74	37	50
Medulla	28	16	60
Cerebral lobes................	196	129	66
Pons......	56	37	67
Corpora quadrigemina	13	9	69
Cerebellum	186	150	81

This table confirms the inferences that might be drawn from what we know of the physiology of cerebral pain. It is rarely to be attributed to irritation of sensory centres, but rather to stretching of the dura mater from effusion into the cavity of the arachnoid or into the internal ventricles; hence irritation of the dural sensory nerve filaments supplied by the trigeminus. As some degree of stretching always takes place, no matter what the seat of the tumor, headache is always imminent, but it may not manifest itself if the tumor grows very slowly and makes way for itself by gradual compression of the brain substance and displacement of its fluids. On the other hand, the pain is most certain to occur, and also to be most violent, when the tumor grows in the cerebellum under the tense fold of the tentorium; it is least likely to occur when room is left for the expansion of the growth at the interpeduncular space. In the pons and medulla, direct irritation of the trigeminus may add a special liability to pain. The great liability to headache with tumors of the corpora quadrigemina may perhaps be due to their intimate connections with the cerebellum. In the cortex, only half the cases are attended by headache; this probably being due to the tendency of the tumor to grow downward, and thus to relieve the tension of the dura. The periodicity in the pain is undoubtedly associated with fluctuations of the circulation, always liable to be diurnally periodic. An initial headache often disappears when paralysis sets in; probably because by that time a zone of softening has usually developed around the tumor. The intensity of the pressure is at first either partially or entirely relieved; headache may set in if the tumor suddenly assume a more rapid rate of growth; it necessarily subsides at the appearance of the terminal symptoms of drowsiness and comatose apathy, the pain being blunted, like other signs of irritation, in the general depression of the sensibility.

Vertigo is a much less frequent but still a prominent symptom of any organic brain disease, and although frequently present with tumor, is far from characteristic of it. It is probably always associated with direct or indirect irritation of those portions of the brain which are concerned in equilibration; and it agrees well with this presumption that vertigo occurs so much more frequently with tumors of the cerebellum than with those of other parts of the brain. It is also frequently observed in tumors of the pons and medulla. Other space-encroaching lesions, *e.g.*, abscesses, so situated as to affect the middle or internal ear, may cause vertigo by the same mechanism as that which is brought into play in ear disease proper—namely, by excitation of the auditory nerve. As the central fibres of this nerve have been traced to the cerebellum, it seems probable that the sensation of vertigo, whether cerebral or aural in origin, is always finally produced by the same mechanism. From the connection of the ocular muscles with the superior olive, and through that with the auditory nerve, paralysis of these muscles by a brain tumor may become an effective cause of vertigo (Bruns).

The third diffused symptom, *Vomiting*, follows the same order of predominance as headache and vertigo, namely, it is much more frequent and severe in tumors of the cerebellum than in those involving some other portion of the brain, with the exception of the corpora quadrigemina, where the liability to vomiting is at the maximum.

From the following table it appears that vomiting is a much less frequent symptom than headache, and occurs later, but follows exactly the same order of predominance, except in respect to the centrum ovale. This is because the vomiting is partly due to the same cause as the headache, namely, the tension of the dura mater and the tentorium. Extreme tension does not, however, always cause vomiting.

TABLE II.

Seat of tumor.	Headache.		Vomiting.		Convulsion.		Choked disc (Bernhardt alone).					
							Amaurosis.		Vision intact.		Total.	
	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.
Cerebral peduncle	4	40	..	..	2	20	....		....		....	
Cerebral lobes..............	129	66	36	18.5	49	26	15 in 124	12	12 in 124	9 =	27 in 124	21
Basal ganglia	19	46	8	19.5	7	19	....		2 in 26	5 =	2 in 26	7
Cortex	37	50	18	23	20	25	5 in 57	8	5 in 57	9 =	10 in 57	17
Pons........	37	67	15	27	2	5	4 in 30	13	2 in 30	6 =	6 in 30	20
Medulla	16	60	12	40	2	6	....		2 in 21	9 =	....	9
Cerebellum	150	83	75	45	18	12	18 in 90	20	13 in 90	14 =	31 in 90	34
Corpora quadrigemina.......	9	69	8	61	1	....	5 in 11	45	1 in 11	10 =	6 in 11	54
Total	401 in 568 cases = 70 per cent.		172 in 568 cases = 30 per cent.		101 in 568 cases = 17 per cent.		82 in 362 cases = 22 per cent.					

Case, by King (*Brain*, October, 1882): Two tumors, one on right side of pons extending to left middle peduncle of the cerebellum, the second embedded in the left side of the floor of the fourth ventricle; convolutions flattened, much serum in ventricles, showing extreme intracranial pressure; but optic neuritis developed only after attacks of coma. Headache, but no vomiting.

The immediate cause of vomiting is supposed to be al-

TABLE III.

Seat of tumor.	INTELLIGENCE DISTURBED.										INTELLIGENCE NORMAL.	
	Mental depression, apathy, loss of memory, imbecility.		Hallucination.		Delirium or mania.		Drowsiness or stupor.		Total.			
	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.	Cases.	Per cent.
Medulla, 29 cases	6	20	2	7	2	7	1	3.5	11	38	18	62
Cerebellum, 162 cases	48	29	1	..	6	3	9	5	64	39	98	60
Cortex, 57 cases	..	...	..	..	..	....	..	....	28	49	..	....
Pons, 56 cases	27	48	1	..	..	....	1	....	29	51.5	27	48.5
Basal ganglia, 40 cases	18	45	1	..	2	....	..	....	21	52	19	47
Lobes, 192 cases	90	46.5	9	4	11	5.5	5	2.5	115	60	77	40
Occipital	1	....	..	..	..	....	..	....	..	....	1	....
Frontal	6	10	..	..	..	....	..	....	6	10	11	19
Parietal	9	15.5	1	..	2	....	7	12	19	33	17	29.5
Temporal	2	3	..	..	..	....	..	....	..	....	..	....
Corpora quadrigemina, 13 cases	4	30	..	..	2	15	4	30	10	77	3	23

ways the excitation of a vomiting centre in the medulla; and this can be brought about by pressure transmitted from any part of the brain. This pressure is, however, more direct when exercised from some point in the posterior cranial fossa; hence a second reason for the intensity of the symptom in cases of tumor of this locality.

The vomiting is unattended by nausea and occurs on an empty stomach and with a clean tongue, and in these respects contrasts markedly with the vomiting of uræmia. It is apt to follow the headache closely, and, as in migraine, to occur at the height of the paroxysm of pain, and also in the early morning.

Epileptiform Convulsions constitute a fourth diffused symptom, which is very characteristic of tumors of the brain. Their causal relations to increased intracranial pressure have been strikingly shown by Leyden's experiments. In these, pressure was directly applied to the brain of animals previously trepanned for the purpose. Convulsions occurred as soon as the pressure had risen to 130 mm. of mercury. Pressure, however, is only one of the mechanisms by which convulsions may be excited. Kussmaul's experiments, made many years ago, showed that sudden anæmia of the brain, such as might be induced by copious hemorrhage, was invariably followed by convulsions. The predominance of convulsions in cases of brain tumor, according to the locality occupied by the latter, does not follow the law which is applicable to symptoms traceable to increased pressure, for convulsions occur oftenest in cases of tumor of the cortex and cerebral lobes, presumably of the portions of the centrum ovale which lie immediately beneath the cortex. General convulsions, therefore, like local spasms, are rendered imminent by direct excitation of the motor tracts. Curiously enough, convulsions are almost excluded from the symptomatology of the pons, though this region, which is traversed in every direction by motor tracts, probably contains the convulsing centre. But apparently the properties of the centre become abolished before they can be effectually irritated. This absence of convulsions, when certain positive signs are present at the same time, is of real value in localizing a tumor in the pons.

As the convulsion is not proportioned to the locality of greatest tension, so it stands in no relation to the time at which tension is greatest. It occurs as an initial symptom, or during the active period of the disease; but it usually disappears, with other irritative symptoms, in some other manner toward the close, when intracranial pressure is at its maximum. Sudden variations in such pressure, caused by fluctuations of the circulation, seem to be the essential proximate cause of the convulsions of brain tumors. The form of the convulsion does not differ from that observed in idiopathic epilepsy, and the diagnosis between tumor and epilepsy is often difficult.

It can be made only by means of the concomitant symptoms. Convulsions occurring in adult life for the first time should at once excite suspicion of brain tumor and lead to an ophthalmoscopic examination for choked disc. According to Bruns, convulsions may occasionally precede for years, and with intermittences of years, all other symptoms of an intracranial growth.

Apoplectiform Attacks occur with brain tumors, and may, though rarely, be the first symptom, and followed by paralysis or paresis. It is extremely difficult, then, to distinguish the case from one of ordinary cerebral hemorrhage. Hemorrhage into or around the tumor is a frequent cause of apoplexy, and thus may first reveal the existence of a tumor hitherto latent; or it may occur incidentally among phenomena already well defined and recognized. Finally, the apoplectic attack may usher in the terminal period; the patient never completely recovering, but passing into a soporose condition and finally into coma. The apoplectic ictus is not invariably associated with hemorrhage; it may be due to sudden alterations of intracranial pressure, by which the functions of brain tissue are temporarily suspended, as after concussion.

Psychic Changes.—The earliest is usually an extreme irritability, which contrasts with the lachrymose emotionality characteristic of softening of the brain. Occasionally this culminates in attacks of maniacal excitement; oftener, however, the patient suffers from melancholic depression, and gradually becomes more and more apathetic and taciturn. This taciturnity, which is a diffused symptom, must be distinguished from true aphasia. As in all mental disturbances, the memory fails. Dementia may precede death for some time, especially if epileptic convulsions have been severe. The specific psychic symptom of brain tumor is drowsiness, from which it is often difficult to rouse the patient. When roused, however, his mind may seem unexpectedly clear. The drowsiness is proportioned to the degree of general intracranial pressure. It is particularly marked in tumors of the frontal lobes, which may reach a considerable size without occasioning other symptoms.

Table III. shows that the liability to psychic symptoms other than drowsiness is not at its maximum when the tumor is seated at the cortex, nor when a cortical tumor is in the frontal lobes. Cortical tumors stand third from the bottom of the scale in this respect; the highest place is occupied by tumors of the corpora quadrigemina, seventy-seven per cent. A relative infrequence of mental disturbances is observed in tumors of the medulla and pons. On the other hand, the high percentage of such disturbances in tumors of the centrum ovale may probably be, at least in part, attributed to their influence upon the cortex. To such influence must, in last analysis, all psychic perversions be ascribed; and the high proportion of cases in which these are present with tumor in any locality of the brain is explained by the extreme sensitiveness of the cortical substance to disturbance of the intracranial pressure from whatever point diffused. Psychic symptoms, of one kind or another, are seen to be extremely frequent in tumors of the brain, being present in about half the cases. Their presence, therefore, materially aids in establishing the diagnosis. Certain specific psychoses, as paranoia and hysteria, are occasionally excited by the presence of a brain tumor.

Choked Disc.—This symptom, when present, is more nearly pathognomonic than any other of brain tumor. According to Oppenheim, ninety per cent. of all cases of choked disc are due to intracranial growths. The choked disc has been differently regarded as the expression of two different morbid processes: an inflammation of the optic nerve, "neuritis optica," or a mechanical obstruction to its circulation, which should be the choked disc proper. Oppenheim notes that in tumors of the base of the cranium, which are liable to obstruct the flow of lymph into the sheath of the optic nerve, the choked disc is usually lacking, and tumors of the optic nerve itself are apt to lead to direct atrophy of the nerve without any preliminary stage of choked disc. These facts are counted as an argument in support of the celebrated doctrine of von Graefe, who attributed the choked disc in all cases to an obstruction offered to the venous circulation of the optic nerve, from immediate or mediate pressure exercised upon the sinus cavernosus; hence a serous transudation from the veins, rendering the papilla swollen and œdematous. As seen with the ophthalmoscope the papilla appears engorged, tumefied, nebulous, irregular, and with ill-defined edges; a spirus of cloud covers both the centre and the circumference, rendering the whole surface opaque. The arteries are diminished in calibre, the veins appear interrupted at various points. In one form the capillaries are increased in size, in the other they are effaced.

TABLE IV.—CASES OF DIFFUSED SYMPTOMS ALONE.

Seat.	Headache.	Headache and vomiting.	Headache and convulsions.	Headache and choked disc.	Headache, convulsions, and vomiting.	Headache, convulsions, and choked disc.	Headache, convulsions, vomiting, and choked disc.	Headache, vomiting, and choked disc.	Vomiting.	Convulsions.	Convulsion and choked disc.	Psychic alteration.	Total.
Cortex, 57 cases	4	3	1	..	..	1	..	..	..	1	1	In 7 of these.......	11 = 19 per cent.
Lobes, 124 cases	5	3	8	2	4	5	..	3	2	4	1	In 22 of these......	37 = 29 per cent.
Basal ganglia, 26 cases	2	1	..	..	..	..	..	..	..	2	..	1 alone, 1 besides..	6 = 23 per cent.
Cerebellum, 90 cases	2	6	1	..	3	..	..	4	..	1	..	In 4 of these.......	17 18.5 per cent.
Total..................	13	13	10	2	7	6	..	7	2	8	2	35	71 = 23.8 per cent.

Bruns considers these two forms simply gradations of each other, the neuritis optica being the incipient stage, the choked disc proper the advanced stage of the same process. When the arteries have almost ceased to be distinguishable, except at the periphery of the retina, small hemorrhages usually form in the retina, and spots of fatty degeneration are seen, the latter being a serious threat of speedy blindness.

Against the doctrine of venous obstruction as a cause of choked disc, it has been urged that the free inosculation of the ophthalmic vein with the angular branch of the facial suffices to avert complete venous obstruction, even when the circulation in the cavernous sinus has been retarded. Further, a free communication has been demonstrated between the intervaginal lymphatic space of the optic nerve and the subarachnoid space of the brain. It has been shown that a rise of intracranial pressure suffices to force cerebro-spinal fluid into the intervaginal space of the nerve, thus causing compression of its central vessels, local obstruction, and swelling from transudation, apart from venous obstructions.

Choked disc sometimes appears in cases in which the tumor is so small that much increase of intracranial pressure seems doubtful. It is then more probably due to inflammation of the optic nerve, first propagated from irritated brain tissue to the central terminations of the nerve, neuritis from diffused cerebritis (Mackenzie), or excited by direct pressure upon the optic tract. Such direct pressure is exercised by tumors of the corpora quadrigemina, the chiasma, the cerebral peduncles, or the interpeduncular space.

Choked disc is found far more frequently (54 per cent.) in cases in which the tumor involves the corpora quadrigemina, than in those in which it involves any other part of the brain. The smallest percentage is in the class of cases in which the basal ganglia are the seat of the tumor. When there is direct pressure on the optic tract, the papilla sometimes atrophies without passing through any stage of choked disc. Until atrophy sets in, vision is not necessarily impaired. Thus, out of a total of 82 cases of choked disc, vision remained intact in 37, or 45 per cent. In a great many cases no ophthalmoscopic examination is made, unless vision is impaired, and this explains why such examination is lacking to the history in 232 out of 485 observations analyzed by Bernhardt (47.8 per cent.). In many of these negative cases it is very possible that choked disc really existed, so that the real proportion of this lesion in brain tumor cannot be considered as known.

The ten per cent. of cases of choked disc which are not caused by intracranial growths have a very diverse etiology. The condition has been seen in pernicious anæmia; in a few cases of arteriosclerosis, when the arteries of the optic nerve are involved; in abscess; in multiple sclerosis.

In a certain number of cases cerebral tumor manifests itself exclusively by one or more of the foregoing "diffuse" symptoms. Among Bernhardt's cases of tumors of the cortex, centrum ovale, cerebellum, and basal ganglia, this limitation may be found 71 times out of a total of 297 cases, or 23.8 per cent.

The existence of mental symptoms in a large proportion of these cases (49 per cent. of them) is the circumstance that might, perhaps, most surely guide in the diagnosis, otherwise so difficult.

The proximate consequences of increased intracranial pressure, which are the immediate cause of the diffused symptoms, have been differently interpreted. It was long maintained that the brain substance was nearly as incompressible as water. Room, therefore, could be made within the cranium for a neoplasm only by proportionate expulsion of blood and lymph, and by atrophy of the brain tissues in the immediate vicinity of the tumor. Adamkiewicz's experiments have shown, however, that the nerve tissue surrounding the tumor is compressed, *i.e.*, its solid molecules are approximated, and the fluid normally interposed between them is, to a greater or less extent, expelled. For, when a piece of laminaria was inserted under the skull of an animal previously trepanned for the purpose, and was allowed to swell, thus rapidly encroaching upon the intracranial space, microscopic examination of the tissue in which the foreign body was embedded revealed the fact that all the nerve elements of this tissue were closely crowded together, thus apparently multiplied in a given space. The zone adjacent to this was intensely vascularized from dilatation and new development of capillaries, and, in addition, it was hypertrophied from proliferation of connective tissue.

In the experiment, the swelling of the laminaria was much more rapid than is the growth of any tumor, and the condensation and nutritive irritation of tissue were therefore exaggerated. To a greater or less extent, however, both these lesions must always be produced by the presence of a foreign body within the cavity of the cranium. Only when the tumor grows very slowly are they absent, or reduced to such a minimum as to occasion no symptoms, either diffused or focal.

The elements of gliomatous tumors are the most liable to so insinuate themselves between the elements of the brain tissue as to avoid compression, and no well defined line of demarcation separates the tumor from the brain mass. In this respect the sarcomata contrast markedly, and may be distinguished by the naked eye by the zone of softening which circumscribes them. Carcinomata and tubercle directly destroy brain tissue and take its place.

The occurrence, in twenty-three per cent. of the cases, of diffused without focal symptoms indicates that the centres of origin of nerve tracts have remained unaffected, though the vomiting and convulsive centres and the nervous filaments of the dura mater have been irritated; that lymph has been forced into the sheath of the optic nerve, or that a descending neuritis has been excited by propagation from the zone of cerebritis surrounding the tumor; and that the delicate psychic mechanisms of the cerebral cortex have been irreparably jarred and are out of working order.

This immunity of motor, sensory, or special-sense nerve functions is usually due to the localization of the tumor in a "latent" portion of the brain; but it is also sometimes observed in cases in which the tumor occupies a (presumable) focus of nerve origin. Thus, although there can be no doubt that the ultimate origin of the motor nerves contained in the pyramidal tracts is in the central gyri and paracentral lobule, tumors seated in these localities have sometimes been observed entirely unaccompanied by motor symptoms, either irritative or paralytic. Two such cases are contained among the eleven of the table. In one of these there were forty hydatid cysts in the brain, a form of neoplasm very frequently latent. In the second case, however, there was a most extensive sarcoma occupying the lower half of the anterior central gyrus, posterior half of third frontal gyrus, and under half of insula.

Two explanations are offered for these cases. First, that the elements of the neoplasm have insinuated themselves so gradually between those of the nerve tissue, or have displaced them with so little injury, that the functions of this tissue have not suffered. This explanation applies to cases in which, instead of the cells of a nucleus of origin, the fibres of a nerve tract have been displaced, as in some extraordinary cases on record in which a tumor has occupied nearly the entire pons, yet has occasioned no motor symptoms. The second explanation applies only to cortical centres. According to Exner, the different mechanisms of the cortex, though specially concentrated at certain localities, exert their influence somewhat beyond these limits, though with constantly diminishing intensity and effectiveness. Hence it is occasionally possible, though the main centre be destroyed, that its action may be supplemented by that of others habitually subordinate.

In more than three-fourths of the cases of brain tumor, in addition to the diffused symptoms hitherto described, the patient suffers from perversions or abolition of one or more cerebral functions other than psychic ones. These are known as the focal symptoms.

The simplest *focal symptoms* are those elicitable by percussion and auscultation of the cranium. In a certain number of cases, careful percussion awakens pain over a definitely limited area; and elicits also a peculiar tympanitic sound (Macewen), indicative of a marked thinning of the cranial bone, and due to the more extensive vibrations of air in the nose and mouth which occur when the skull is thinner than normal. In a few rare cases auscultation discovers another sound, an arterial murmur synchronous with the arterial pulse. This is conspicuously heard with aneurisms, but is by no means confined to them. It is analogous to the murmur which may be heard in rachitic children or in those with open fontanels, or even in certain cases of intense anæmia. Other focal symptoms, and far more frequently encountered than the foregoing, depend on the perversion or abolition of mobility or sensibility in one or more cranial nerves or spinal nerve tracts; or on similar alterations of one or more of the special senses. Among the latter, however, is to be excepted the impairment of vision directly traceable to choked disc or optic neuritis. An intense interest has recently attached to these symptoms as a means of unravelling the physiological problems of the localization of brain functions. For this purpose, however, the study of tumors is much less valuable than that of other brain lesions, such as, for example, localized softening; for their limits are irregular, and their effects, through transmission of pressure, often diffuse themselves in structural or functional changes far beyond these visible limits. For clinical purposes, therefore, it is necessary to ascertain first what symptoms are generated by lesions really limited to certain localities; second, to what extent the complication of these by others, diffused or symptomatic of different localities, may aid us in diagnosing a tumor instead of any other focal disease.

Focal symptoms are always unilateral at the beginning—a most useful criterion in distinguishing tumor from diffused disease of the brain. The appearance of symptoms on the side of the body opposite to that where they first began indicates an extension of the tumor across the median line, except when parts are affected which are endowed with bilateral cortical innervation. Extension of the growth across the median line, for obvious reasons, most frequently occurs at the narrowest regions of the encephalon, the pons and (though less frequently) the medulla. It is, however, also seen in tumors of the corpus callosum, but the second hemiparalysis is much slighter than the first.

Case (Bristowe, *Brain*, October, 1884): Illness twelve weeks. Left hemiplegia, gradually extending to right side; then general paralysis, principally on the left side, ten days before death. Progressive drowsiness or stupidity, aphasia. Sarcoma occupied anterior two-thirds of fornix and corpus callosum, extending into the centrum ovale in both hemispheres, but principally in the right.

In addition to these symptoms involving purely cerebral functions, the functions of respiration and circulation are sometimes modified from the direct or indirect morbid influence exercised upon the medullary centres.

Lesions of Motility.—These are by far the most numerous, the most varied in character and in combination of all the focal symptoms of brain tumor. They belong to three different classes: First, irritative, including tremors, choreiform movements, local spasms,* and Jacksonian epilepsy; second, paralytic, consisting in the partial or complete abolition of motive power; third, ataxic, implying inco-ordination among functionally combined movements.

Irritative Lesions of Mobility.—A fine tremor or a clonic spasm, incessant or periodically repeated, is often seen, either in muscles which have already become paralyzed, or in those which become paralyzed at a later date.

Case (Berger, *Arch. der Heilkunde*, XIX. Jahr.): Woman, aged forty-eight. During a year, about every eight days, an attack of clonic spasms in the right arm, then paralysis of the same arm, followed by paresis of the buccal branches of the right facial; clonic spasms persist after paralysis sets in; death a week later. Tumor in left anterior central gyrus, compressing the posterior and second frontal gyri.

Case (Berkley, *Med. News*, 1882): Patient with spasm of the left angle of the mouth for two and a half years. Sudden death from cardiac disease. Calcareous nodule three-sixteenths of an inch in diameter on the right ascending frontal convolution, an inch and a half above the fissure of Sylvius; the locality corresponds to Ferrier's centre for the zygomatic muscles.

Tremors and localized spasms are valuable diagnostic symptoms; for, first, they are more frequent with tumors than with other localized brain lesions; second, they are more frequent in the cortex; and, third, they are especially frequent in the motor zones. All these circumstances are demonstrated by the following tables. The first is compiled from Exner's collection of one hundred and sixty-four cases, exclusively of cortical lesions.

Tumors of cortex (44 cases): Spasm, 3 = 6.5 per cent.; spasm and paralysis, 14 = 31 per cent.; paralysis, 14 = 31 per cent.; no motor symptoms, 13 = 29 per cent. Total spasm, 17 = 38 per cent.

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* The general epileptiform convulsions being a diffuse symptom.

Other lesions of cortex (100 cases): Spasm, 1 = .09 per cent.; spasm and paralysis, 13 = 11.5 per cent.; paralysis, 62 = 56 per cent.; no motor symptoms, 36 = 32 per cent. Total spasm, 14 = 12 per cent.

Thus, in more than one-third of all cases of brain tumor, localized spasms or contractures exist at some period of the disease. When present, they indicate a greater probability of localization in the cortex than in any other part of the brain; and after that, in the region of the corpus striatum and thalamus opticus. In the table, the highest percentage falls to tumors of the peduncle; but this fact is offset by the great rarity of tumors in this region.

TABLE V.—PROPORTION OF CASES OF SPASM WITH TUMORS.

Seat.	Number of cases.	Spasm.	Spasms and paralysis.	Paralysis.	Total spasm.	Percentage.	No motor symptoms (except ataxic).
Cortex							
Central gyri..........	39	4	24	10	28	71	2
Parietal lobe (motor).	11	..	7	1	7	63	3
Total motor zone ..	50	4	31	11	35	70	5
Frontal gyri	14	2	1	4	3	21	7
Other latent parts....	13	1	2	2	3	23	8
Total cortex	77	7	34	17	41	53	Per cent. 20 – 25
Centrum ovale	124	12	22	45	34	27	45 = 36
Basal ganglia	41	9	10	14	19	46	8 = 19
Peduncle	10	1	5	3	6	60	2 = 20
Corpora quadrigemina .	13	1	3	2	4	30	7 = 53
Pons..	56	3	7	38	10	17	8 = 14
Cerebellum	165	20	12	26	32	19	107 = 64.5
Medulla	30	8	2	15	10	33	5 = 16
Total	516	..	..	..	156	30	202 = 37.5

It is evident that spasmodic contractions of muscles may be caused by irritation either of the nerve elements of a motor centre, or of the fibres of a motor tract descending from it, but that the first condition is more favorable. A continuous fibrillary twitching is frequent in cortical tumors. But tumors of the pons and medulla are rarely accompanied by spasm; it seems that the liability to irritation increases higher up in the tract, and also when the latter is more incompletely invaded. Irritation of the skin over the affected muscles will often throw them into spasm.

Paralyses of Motility.—These are especially characterized, as a rule, by their gradual development, a circumstance which is most useful in distinguishing brain tumors from hemorrhage. It does not, however, serve to differentiate tumors from softening, for in the latter the paralysis is also gradually developed.

To a certain extent the paralyses of tumors share the peculiarities of those caused by other lesions of the same locality. As already stated, however, in the case of tumors, the paralyses are rarely purely typical throughout the whole course of the disease, because they constantly tend to encroach upon other regions than that in which they originated; and because their influence, by transmitted pressure and nutritive irritation, is apt at all times to diffuse itself considerably beyond the region which they visibly occupy. A paralysis which may seem at a given stage to be entirely atypical may, however, exhibit in the history of its development peculiarities which point out the true nature of the disease. The local diagnosis is best assured when a localized spasm has passed gradually into a localized paralysis. The paralysis has been preceded by a slowly progressing paresis, or by tremor or spasm in the affected muscles, or has existed in one set of muscles, or in one limb, or in one or more cranial nerves; or there has been a combination of paralyses of such nerves with others of the extremities, before the disease reached its complete evolution. Or, further, the very first appearance of paralysis may have been preceded by one or more diffused symptoms; or it may have been ushered in by an epileptiform convulsion or an apoplectic attack, remarkable for its brevity and incompleteness. Or a paralysis may declare itself at once, in a fully developed form, but isolated, as in one facial nerve, and after prolonged headache, attacks of vomiting, and change of mind or character of the patient. The typical characteristics of the paralyses, according to locality, are as follows:

Cortex.—The paralysis, at the outset at least, is "dissociated," monoplegic. One arm or one side of the face is affected, or the two together are affected on the same side. It is extremely rare that paralysis begins in the leg; but this extremity often becomes involved later, and then the patient suffers from a complete hemiplegia, difficult to distinguish at first from the common hemiplegia due to hemorrhage into the internal capsule. It is very rare, however, that the paralyzed limbs become rigid. It is with tumors in this region that clonic spasms are most frequent, either before or during the paralysis. Symptoms of tumors of different regions of the cortex follow, approximately, the rules which have been laid down for other lesions, according as they occupy the "latent" or the motor zones. The latent regions are those parts of the brain in which, with rare exceptions, lesions produce no motor symptoms. The motor zones are those whose lesions are always followed by spasm or paralysis, except in a very few cases, in which the absence of symptoms is explained by the extremely slow growth of the tumor, which allows nerve tissue to accommodate itself to increased pressure. When an "absolute field" exists it will be found that, in all cases in which motor symptoms are absent, this field is entirely free from lesion. In the regions adjacent to these, lesions sometimes do and sometimes do not produce symptoms. This fact, as already stated, has been explained in two ways—by the theory of transmitted pressure, and by the theory of a "relative field," which contains motor mechanisms of less degree of intensity and concentration than those belonging to the "absolute field." The absolute motor zones are:

First, for the upper extremity, the anterior central convolutions, especially the lower two-thirds, the upper half of the posterior central convolution, the paracentral lobule, and, in the left hemisphere, the greatest part of the superior parietal lobe, and possibly a few points on the occipital.

Second, for the lower extremity, it is the upper third of both central convolutions and the paracentral lobule, and in the left hemisphere again the greater part of the superior parietal lobe. This "absolute field" is, according to Exner, surrounded by a relative field which occupies the posterior half of the superior frontal gyrus, almost the entire convex surface of the other two frontal gyri, both parietal lobes, and the upper part of the occipital lobe. This field belongs to both extremities.

The centres for the muscles of the trunk have been placed by Horsley and Schäfer in the gyrus marginalis.

Third, there is no absolute field for either facial muscles or tongue, the mechanisms for both seeming to be diffused over the greatest part of the hemispheres. But the seat of greatest concentration, for the facial nerve, exists at the lower half of the anterior central gyrus and the lower third of the posterior central; while a relative field extends over the posterior half of both lower frontal gyri and the anterior part of the supramarginal gyrus. The principal centre for the hypoglossal nerve is the lower part of the anterior central gyrus and adjacent part of the middle and inferior frontal gyri.

Fourth, no definite cortical field has been outlined for either the motor-oculi nerve or the trigeminus. In regard to the first, however, it seems certain that all the branches of both nerves are influenced by the centres of a single hemisphere.

The zone for common sensibility coincides with the motor zone as above defined.

Fifth, the zones latent in regard to motor or sensory symptoms include all the frontal lobes, the temporo-sphenoidal lobes, the parietal lobe of the right hemisphere, and the occipital lobes. Lesions of these lobes may remain absolutely latent, and did so in 13 of Exner's 44 cases of tumors, that is, in 29 per cent. But, even when unattended by paralysis or spasm, lesions of these latent zones are liable to be followed by such disorders of speech, of vision, or of hearing as lead to the localization, within their boundaries, of the centres for these important functions.* In Table V. it will be seen that there were 9 cases of paralysis, with or without spasm, occasioned by tumors in the non-motor regions; the percentage of paralysis to whole number of such tumors being 37 per cent. Out of the whole number of cases of paralysis from 77 tumors of the cortex (51 cases), the percentage belonging to tumors of non-motor regions was 17.5 per cent.; that of those belonging to motor regions (42 cases) was 54 per cent. of the whole, and 84 per cent. of the tumors of that region; while, finally, the probability that a tumor situated in the cortex would occasion some form or degree of paralysis is indicated by the relation of 51 to 77, or 66 per cent.

Centrum Ovale.—A much larger percentage of tumors remain latent in this region than in the cortex, as, for example, 36 per cent., instead of 25 per cent. (see Table V.). The absence of symptoms is to be expected when the tumor neither occupies nor affects bundles of fibres coming from the motor regions of the cortex. In the following table Ladame's and Bernhardt's cases are combined, and show to what extent tumors situated in non-motor regions may yet inhibit the mechanisms of the motor regions.

TABLE VI. PARALYSIS WITH TUMORS OF CENTRUM OVALE.

MOTOR REGIONS.			NON-MOTOR REGIONS.		
Seat.	Paralysis.	No paralysis.	Seat.	Paralysis.	No paralysis.
Pars centralis anterior and posterior (Petres)	61	16	Pars frontalis	37	37
			Pars occipitalis	10	23
			Temporal lobe	2	3
			Other parts	..	7
Total	61	16	Total	49	70

The paralyses which are associated with tumors of this region present nearly the same characteristics as do those associated with tumors of the cortex if they are near the surface; that is, they are liable to be monoplegic; but they resemble those of tumors of the internal capsule, if they approach the basal ganglion, in which case they may become completely hemiplegic, and may be followed by rigidity. Tumors in the anterior part of the centrum are chiefly indicated by motor symptoms, spasm or paralysis; those situated posteriorly cause sensory symptoms—hemianæsthesia, or pains on one side of the body. Usually a long period of paresis precedes that of complete paralysis.

The percentage of cases of paralysis in tumors of the centrum ovale, whether calculated from the smaller number of cases in Table VI. or from the larger number in Table V., is about the same, viz., 54 per cent. in the first case, 56 per cent. in the second.

Basal Ganglia.—Tumors of the corpora striata, optic thalami, and lenticular nuclei occasion hemiplegias, which often differ from those of hemorrhage in the same region, exclusively by their gradual rate of development. The paralysis is, however, sometimes monoplegic; thus, out of 41 cases, it was confined to the facial nerve four times, to the arm once, to the arm and facial once, and to the leg once. It is extremely remarkable that large tumors may exist in this region without causing any symptoms whatever. This is the rule for tumors limited to the thalamus or to the lenticular nucleus. Acute lesions, such as hemorrhage in the latter ganglion, cause temporary hemiplegic symptoms, but these subside, probably because the function of the destroyed tissue is supplemented by that of other motor centres. But such temporary paralyses are not seen with chronic lesions, as, for example, tumors, unless these are complicated by an accidental hemorrhage.

But tumors limited to the corpus striatum will certainly cause paralysis if they involve the anterior two-thirds traversed by the motor tract of the internal capsule. It is injury to this tract which determines the phenomenon of "late rigidity"; a phenomenon depending on the descending degeneration which reaches the spinal cord, and which, though so commonly seen after cerebral hemorrhage, is not peculiar to that lesion, but only to the locality which it most frequently occupies.

If a tumor involve the posterior third of the internal capsule, whose fibres pass between the corpus striatum and the thalamus, it tends to destroy the sensory fibres which pass in this locality (Charcot, Veysière), and causes a hemianæsthesia in addition to the motor paralysis. This complication is therefore of great use in establishing the diagnosis of tumors of this region, which from their encroaching tendencies are so liable to involve all parts of the internal capsule. It is possible that a transmitted irritation to sensory fibres has something to do with the high percentage of spasms observed in tumors of the basal ganglia (46 per cent., see Table V.). There were 24 cases of paralysis, with and without spasm, which is 58 per cent. of the whole number.

Hemianopsia, or paralysis of some ocular muscles, occurs with such tumors of the thalamus as touch upon the corpus geniculatum externum. Athetoid movements and intention tremor are very characteristic of thalamic tumors. Still more so is Bechterew's symptom, namely, preservation of the innervation of facial muscles for voluntary movements, with loss of the automatic movements involved in emotional expression,—as in laughing or crying. This isolated mimetic paralysis seems to be quite peculiar to lesions of the thalamus.

Peduncle.—As might be expected, tumors of this region cause hemiplegic paralysis in almost all cases (eighty per cent.). Together with the extremities, the facial nerve and also the hypoglossus are usually involved. The most characteristic circumstance, however, is the paralysis of the motor-oculi nerve by direct pressure upon its trunk as it emerges in the interpeduncular space. The paralysis is on the same side as the tumor, that is, on the side opposite to the hemiplegia. The paralysis is usually total, in which case there will be unilateral dilatation of the pupil, ptosis from paralysis of the levator palpebræ muscle, and divergent strabismus from paralysis of the internal rectus. In other cases, one or more of these symptoms may exist alone As the tumor grows larger it sometimes crosses the interpeduncular space, and compresses the nerve on the opposite side. This important symptom existed in seven out of the ten cases of Ladame and Bernhardt. It is not, however, absolutely pathognomonic of lesions of the peduncle; for it results, with exactly the same forms, from every tumor of the interpeduncular space; thus, from those springing from the base of the cranium.

Corpora Quadrigemina.—Tumors of these bodies lie outside of the direct cerebro-spinal motor tracts, and thus produce much less definite motor symptoms. Some degree of paralysis existed in 5 out of 13 cases; in 1, paresis of the arm and facial nerve; in 2, a unilateral facial paresis; in 1, paresis of one leg; and in 1, paresis of one-half of the body.

On the other hand, the motor-oculi nerve seems to be paralyzed as often as in the case of tumors of the peduncles; a fact which might be expected from the proximity of the corpora quadrigemina to the nuclei of the nerves, which lie immediately below them. In 14 cases, divergent strabismus existed in 8 (5 cases of Bernhardt, 3 related by Nothnagel). In 1 other case, the abducens was paralyzed, so that internal strabismus existed (Gowers, *Lancet*, 1879).

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* The wide diffusion of the mechanisms for the motor-oculi nerve and the facial, which render their paralyses of little value in regional diagnosis, is probably correlated to the complex relations of these two nerves to the mechanisms of psychic existence, and their functions in the innumerable shades of facial expression.

Cerebellum.—Absence of true motor paralysis, taken together with impairment of the power of equilibration, is highly characteristic of tumors of the cerebellum. Out of a total of 165 cases, only 38 showed any kind of paralysis (23 per cent.). This is almost the proportion in which the symptom is absent in tumors of the cerebral cortex. Excluding the cerebellum and corpora quadrigemina, the probabilities of paralysis with brain tumor are expressed by the percentage 89, while for the cerebellum and corpora quadrigemina alone the percentage is only 24.

Tumors of either lateral lobe of the cerebellum cause of themselves no motor symptoms, even ataxic, and may be completely latent. Out of the 38 cases of paralysis the tumor occupied the middle lobe of the cerebellum in 4; in 5, one of the peduncles; in 15, though mainly situated in a lateral lobe, it extended into the middle lobe, or else compressed the pons or medulla.

The facial nerve may be affected either by an isolated, or by an alternating, or by a hemiplegic paralysis, in the rare cases in which hemiplegia occurs. The lesion is never really of cerebellar origin, but always secondary to encroachment upon the pons or medulla.

Pons Varolii.—In this locality tumors produce the most extensive and also the most complex combinations of paralyses. They are occasionally paraplegic, and not infrequently they become, little by little, generalized throughout the four limbs. This creeping generalization is highly characteristic of tumors of the pons. On the other hand, only cranial nerves may be affected.

Case (Wernicke, *Archiv f. Psychiat.*, Bd. vii.): Patient aged fifty-eight years. In July, headache, diplopia; difficulty in opening and shutting mouth. By end of August, paralysis of left facial nerve, including upper branches; rigidity of left masseter; eyes persistently deviated toward the right; diminished sensibility of face and head on the *right* side, that is, on the side opposite to the facial paralysis. Death occurred in October without further motor affection. Section discovered a tumor on the floor of the fourth ventricle, on the left side of the middle line. Associate nucleus of facial and abducens completely destroyed; left facial nerve nucleus, as also part of the fibres of the right trigeminus, destroyed.

After the frequent generalization of the paralysis, the remarkable paralytic symptoms of pontine tumors are: 1. The coexistence of hemiplegic paralysis of the extremities with paralysis of one or more cranial nerves on the opposite side of the body: alternate paralyses. 2. The occurrence of a *persistent* conjugate deviation of the eyes, thus distinguished from the same symptom in lesions of the hemispheres, where it is always transitory. To these positive symptoms may be added an important negative characteristic, namely, the nearly complete absence of local irritative symptoms, and, to an even more marked degree, of general convulsions. The alternate paralyses are produced by tumors in the lower part of the pons, which injure the nerve nucleus or compress the nerve trunk on the side on which they are situated, and injure the general motor tracts of the limbs previous to their decussation, so that the resultant hemiplegia follows the usual law for cerebral paralysis, and appears on the side of the body opposite to the lesion. When the tumor occupies the upper segment of the pons, anterior to the cerebral peduncles, the facial paralysis will be on the same side as the limbs, since it depends not on a lesion of the nucleus or nerve trunk, but on one involving the central fibres after their decussation. When the tumor occupies the region of the abducens nucleus, the movements of both eyeballs to that side are paralyzed. The double nature of the paralysis proves that the nucleus common to the abducens and internal rectus has been affected.

In the most typical cases, all the branches of the facial are paralyzed, including those innervating the orbicularis palpebræ. The eye cannot be closed, and the patient presents the appearance of Bell's paralysis. The electric excitability of the nerve may then be diminished. However, neither of these last conditions is invariable, even when the paralysis is alternate.

Double facial paralysis is extremely rare. It is lesions of the pons which have furnished the explanation of the remarkable phenomenon—conjugate deviation of the eyes—which for a long time puzzled pathologists. This deviation implies paralysis of the abducens nerve of one side, supplying the external rectus, and coincident paralysis of a branch of the motor-oculi nerve supplying the internal rectus on the opposite side. The apparent remoteness from each other of the nuclei of origin of these two nerves rendered this phenomenon extremely difficult to understand, until the discovery was made, in the pons, of a common nucleus, which unites fibres of the abducens with fibres from the lower nucleus of the motor-oculi on the opposite side. Destructive lesions of this associate nucleus are followed by a permanent conjugate deviation, as in the case (Wernicke) above quoted. It becomes evident that the transitory deviations of the eye, frequently seen immediately after an attack of hemorrhage into any part of the brain, are due to a remote shock propagated to this same nucleus.

The abducens nerve is not infrequently paralyzed alone, causing a converging strabismus of the affected eye.

Isolated paralysis of the motor-oculi nerve is much more rare, and is seen only when the tumor or its influence extends above the pons into the cerebral peduncles, or above them to the nerve nuclei. Ptosis, from isolated paralysis of the levator palpebræ branch, has sometimes been observed alone, and, so far, in cases of tumors, but not in those of any other lesion. This symptom would, therefore, be useful in differential diagnosis.

Paralysis of the hypoglossus is not rare. It is indicated by an impairment of the voluntary movements of the tongue and by disturbance of speech, dysarthria. This paralysis alternates with that of the extremities. It is distinguished from progressive bulbar paralysis by absence of atrophy of the tongue.

The motor branch of the trigeminus is sometimes paralyzed, more often irritated, causing, in the latter case, spasmodic trismus or clonic convulsions of the muscles of mastication.

Difficult deglutition is also sometimes present, but does not seem to be attributable to paralysis of the pharynx muscles, but rather to be a secondary consequence of paralysis of the tongue and of certain muscles innervated by the facial nerve, the styloglossus, digastricus, and stylohyoideus (Nothnagel).

The following table exhibits the various combinations of paralyses, which have been observed with tumors of the pons.

TABLE VII.—MOTOR PARALYSES WITH TUMORS OF PONS (56 CASES).

Cranial nerves alone.		Limbs alone.		Combination of limbs and cranial nerves.		No motor symptoms.
3d nerve......	2	Hemiplegia...	7	*On same side.*		4
7th nerve.....	3	Paraplegia....	3	Hemiplegia and 7th nerve........	4	
3d and 6th nerves......	2	Four extremities........	2	*Alternate paralysis.*		
6th and 7th nerves......	3	Arm alone....	1	Hemiplegia and—		
7th and 12th nerves......	1			3d nerve........	2	
3d, 7th, and 12th nerves..	1			6th nerve.......	3	
3d, 5th, 7th, and 12th nerves..	1			7th nerve........	4	
				3d and 6th nerves	1	
				3d and 7th nerves	3	
				6th and 7th nerves........	5	
				3d, 6th, and 7th nerves........	1	
				3d, 5th, 7th, and 12th nerves...	1	
				3d, 6th, 7th, and 12th nerves...	1	
Total......	13	Total......	13	Total.........	25	4

The number of cases in which the cranial nerves or those of the limbs were paralyzed independently of each other is, in this collection of cases, exactly equal. The number of cases of combined paralyses is just double that of either of the classes of isolated paralyses. Among the cranial nerves, the liability of the facial is evidently the greatest; it was affected, alone or in combination, twenty-four times; the abducens sixteen times.

Medulla.—In this region the liability to paralysis again diminishes. Tumors of the medulla are not infrequently confined to the floor of the fourth ventricle, so that the motor tracts and nuclei are both left uninjured. In this case, the patient escapes all paralysis; indeed, he often remains with singularly few symptoms for the subject of an organic disease seated so near to vital nerve centres. Out of 30 cases, 12, or nearly half, remained free from motor symptoms. In one case, so far unique (Erichsen, *Petersb. med. Zeitschr.*, 1870), a bilateral paralysis of the vocal cords was noted, due to lesion of the accessory nerve.

TABLE VIII.—MOTOR PARALYSES WITH TUMORS OF MEDULLA (30 CASES).

Cranial nerves alone.	Extremities.	Combination.	Negative.
3d nerve 2	Hemiplegia ... 1	Hemiplegia and—6th nerve .... 1 *Same side.*	12
7th nerve 2	Three extremities 1	Hemiplegia and—6th nerve (alternating) 1	
3d and 7th nerves 1	Paraplegia 2	3d, 6th, and 7th nerves 1	
7th and 11th nerves 1	General 2	3d, 7th, and 12th nerves 1	
5th, 6th, and 7th nerves... 1		7th and associated 3d and 6th nerves 1	
Total 7	Total 6	Total 5	12

The third form of motor lesion is *ataxia.*

This form of lesion is principally seen with tumors of the cerebellum and corpora quadrigemina; the latter, possibly from the connection of these bodies with the cerebellum through the superior cerebellar peduncles. In the pons and medulla, the advent of paralysis is often preceded for some time by a staggering or reeling gait "like a drunkard's." This same symptom is very conspicuous in tumors of the cerebellum, and, when associated with the negative symptoms of absence of motor or sensory paralysis, points very strongly to tumors of this region. For the development of the symptom, however, it is essential that the middle lobe be involved or indirectly affected; tumors limited to a lateral lobe are characteristically latent.

Forced movements, or inclinations of the body or head to one side or the other, are sometimes associated with tumor in a lateral peduncle on the corresponding side. A tendency to fall forward or backward has been associated with the situation of the tumor in the anterior or posterior extremity of the upper or lower processus vermiformis (middle lobe).

A combination of ataxia with ocular paralyses was pointed out by Nothnagel to be highly characteristic of tumors of the corpora quadrigemina.

Recently there has been described an ataxia in tumors of the frontal lobes closely resembling that supposed to be special to the cerebellum. It is due to paralysis of the muscles of the trunk, whose centre of cortical innervation is placed by Horsley and Schäfer in the gyrus marginalis, thus in the middle line. Hence with a unilateral tumor there will be bilateral ataxia.

LESIONS OF SENSIBILITY.—With the exception of headache, already described as a diffuse symptom, alterations of sensibility are very much less prominent in the symptomatology of tumors than alterations of motility.

It is evident from this table that, in the cortex, the seat of sensibility coincides with the seat of motility. Pain or anæsthesia rarely exists without paralysis, or except in connection with tumors situated in the motor zones. The liability to pain, other than headache, with tumors of the centrum ovale, is very slight (5 cases out of 124).*

It has already been pointed out that tumors of the basal ganglia will cause hemianæsthesia in paralyzed limbs, provided they involve the bundle of fibres which pass in the posterior third of the internal capsule; otherwise they will not be attended by lesions of sensibility. The table, therefore, expresses the probabilities of this precise situation, in giving the proportion of cases of pain or anæsthesia as eight out of thirty-nine, or twenty per cent.

The highest percentage is with tumors of the pons, and the next highest, if the few cases of tumors of the peduncles of the cerebrum be excluded, is with those of the medulla. In these places occur pain and anæsthesia in the facial range of the trigeminus. When similar symptoms are excited by tumors of the cerebellum, it is only because the pons or medulla has been compressed.

TABLE IX.—LESIONS OF SENSIBILITY WITH BRAIN TUMORS.

Seat.	WITH MOTOR PARALYSIS.						WITHOUT MOTOR PARALYSIS.						Negative.	No. of cases. Total percentage lesions of sensibility.
	Unilateral.		Double.		Trigeminal.		Unilateral.		Double.		Trigeminal.			
	Pain.	Anæsthesia.	Pain.	Anæsthesia.	Pain.	Anæsthesia.	Pain.	Anæsthesia.	Pain.	Anæsthesia.	Pain.	Anæsthesia.		
Cortex (57 cases):														
Central gyri	6	7	....	....	....	....	1	....	....	....	....	....	11	14 = 56
Parietal gyri	1	3	....	....	....	....	....	1	....	....	....	....	12	5 = 29
Frontal gyri	....	....	....	....	....	....	1	....	....	....	....	....	9	1 = 10
Temporal	....	2	....	....	....	....	....	1	....	....	....	....	1	3 = 75
Occipital	....	....	....	....	....	....	....	....	....	....	....	....	1	0 = 0
Entire cortex	8	15	....	....	....	....	....	....	....	....	....	....	34	23 = 40
Centrum ovale (124 cases)	5	14	....	....	....	....	....	....	....	....	....	....	105	19 = 15
Basal ganglia (39 cases)	1	5	....	....	....	....	....	2	....	....	....	....	31	8 = 25
Peduncle (10 cases)	1	3	....	....	...	....	....	....	....	....	1	....	5	5 = 50
Pons (51 cases)	Same side, 1.	10	....	....	2	....	....	....	....	....	....	....	24	27 = 52.5
	Opp. side, 7.	....	....	2	....	5	....	....	....	....	....	....		
Medulla (30 cases)	4	5	....	2	1	1	....	1	....	....	....	....	16	14 = 46
Cerebellum (167 cases)	2	7	....	1	1	4	5	5	....	....	....	....	142	25 = 14.5
Corpora quad. (13 cases)	1	....	....	....	....	....	1	....	....	....	....	....	11	2 = 15
Total (491 cases)	30 = 6% of all cases.	59 = 12%	....	5 = 1%	4 = 0.8%	10 = 2%	8 = 1.2%	8 = 1.6%	....	....	1	....	368	....

Percentage of lesions of sensibility in all cases equals 25.

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* The percentage of headache, however, was sixty-six, the highest after the cerebellum and rare cases of corpora quadrigemina. The liability to headache, from distention of the dura mater, is constantly seen to bear no proportion to perversions of sensibility due to lesion of sensory tracts or centres.

Trigeminal neuralgia or anæsthesia is, like cramp or paralysis of the masticatory muscles, a most important symptom for helping to localize a tumor in the posterior cranial fossa. It is noticeable (see table) that trigeminal anæsthesia has hitherto been observed on the side opposite to the paralysis, while anæsthesia of the extremities has nearly always existed on the same side.

The cerebellum and corpora quadrigemina show the same minimum liability to lesions of sensibility as they do to motor paralysis. Their precentage, almost alike for the two cases, is, however, not lower than that of the centrum ovale.

LESIONS OF THE SPECIAL SENSES.—*Vision.*—Disturbances of vision are extremely frequent as symptoms of brain tumor, and are of three kinds: First, atrophy of the optic papilla as a consequence of choked disc, and therefore as a remote consequence of increased intracranial pressure; second, deviations of the eyeball or eyelids from isolated or combined paralyses of the nerves supplying the ocular muscles, the third, sixth, and seventh; and finally, third, amblyopia or amaurosis, resulting from direct affection of the optic nerve in its course through the cranium, or at its cerebral centres, the mode of development being therefore almost precisely analogous to that of paralysis of any other nervous tract by direct compression. The first two kinds of ocular defect have been sufficiently described; the third comprises two different kinds of lesions, those affecting (by compression) the optic tract or chiasma, and those which affect the optic stations at the posterior extremity of the thalami or at the corpora quadrigemina, or else at the final visual centres of the cortex.

The optic nerve or chiasma is liable to compression from tumors arising from the base of the cranium or from the hypophysis, and also from tumors of the peduncle; an acute descending optic neuritis, with atrophy of the papilla, is usually excited. When one tract or one side of the chiasma is compressed, hemiopia results, a phenomenon dependent on the semi-decussation of nerve fibres which takes place in the human chiasma. Thus pressure on the right side beyond the chiasma, of such a nature as to injure the fibres of one tract, will abolish vision in the right half of both eyes. A tumor in front of the chiasma may cause temporal hemiopia of both eyes, since it injures fibres coming from the nasal half of both eyes. There is no way in which a double nasal hemiopia can be produced by tumors at the base of the brain.

Tumors of the thalamus might be expected to affect the sight from lesion of the corpus geniculatum, with its branch to the optic tract. As a matter of fact, however, blindness is not very common from tumors of this locality—only 5 cases out of 26 (19 per cent.) As already mentioned, hemianopsia is seen with tumors of the thalamus, when they involve the corpus geniculatum externum. Tumors of the corpora quadrigemina, however, have an immensely large portion of cases. Out of 11, 9 showed either amblyopia or amaurosis, 5 with and 4 without choked disc (81 per cent.).

Visual defects from lesions of the cortex are extremely interesting in connection with two physiological problems, viz., the question of a second decussation of optic-nerve-fibres in the cerebrum (Charcot), and that of the localization of the mental centre of vision. This centre was placed by Ferrier at the angular gyrus, as an inference from direct experiment upon the brain of monkeys. But Exner, on the authority of four cases of lesion reaching to the cortex, of which two were tumors, places the visual centre in the first and second occipital gyri—the cuneus and adjacent part of the lobulus quadratus.

Case (Gowers, *Lancet*, 1879): Visual hallucinations of a peculiar nature, associated with some degree of amblyopia, affecting both eyes, but more markedly the left. Tumor occupying first and second occipital gyri, posterior half of superior and inferior parietal lobes, the cuneus, and a part of the lobulus quadratus.

Case (Jastrowitz, *Centralbl. für prakt. Augenheilkunde*, vol. i., 1877): Paralysis of both right extremities and facialis; aphasia, with agraphia; hemianopsia dextra. Tumor of the left occipital lobe, principally in the occipital gyri and the precuneus.

Case (Pooley, *Arch. f. Augen- und Ohrenheilk.*, Bd. vi.): Together with various characteristic symptoms of brain tumor in a syphilitic man, extensive binocular hemianopsia. Tumor in posterior lobe of left hemisphere, surrounded by extensive zone of softening. Left thalamus completely softened.

A tumor of one hemisphere may thus cause double hemiopia, a single or double amblyopia or amaurosis, and visual hallucinations of various kinds. The double hemiopia from unilateral lesion, has been interpreted as a proof that, arrived at the cerebral hemispheres, optic fibres which had decussated in the chiasma, recrossed to the opposite hemisphere, thus finally arriving at the same side of the retina as that from which they started. Hemiopia is habitually unaccompanied by choked disc. Crossed homonymous hemianopsia is the characteristic local symptom of disease of the occipital lobes. The symptom occurs also with lesion of any portion of the optic tract, from the chiasma to the occipital cortex. When the lesion is in the medulla of the left occipital lobe, to the hemianopsia is added another important symptom complex, namely, alexia and optic aphasia. It is determined by injury to the association tracts running through the left occipital lobe from the occipital convolutions on both sides to the speech centre in the left superior temporal convolution. The patient recognizes objects by sight, but is unable to name them, unless he either feels, hears, smells, or tastes them. He cannot read words, but can write spontaneously and under dictation. Mind blindness indicates with certainty lesion of the occipital lobes (Bruns).

Six cases of amblyopia and amaurosis have been observed with cortical tumors, unaccompanied by choked disc. These are all to be attributed to a lesion of the visual centre; and, when located in the frontal lobe, the lesion must be regarded as indirect. The amaurosis or hemiopia, with tumors of the centrum ovale (thirty-nine cases, or thirty-one per cent.), probably always implies a transmitted lesion of the cortical visual centre. Of the two cases of hemiopia, referred to in table X., one is used by Exner and Nothnagel as documentary evidence in support of the theory of a visual centre in the cortex of the occipital lobe, but it is placed by Bernhardt among the tumors of the lobes. The total percentage of blindness is higher with tumors of the cerebellum than with those of any other locality, except the corpora quadrigemina. Out of 91 cases there are 41 with some degree of blindness (45 per cent.). Of these, 23, or nearly half, are without choked disc; the blindness being therefore due to the direct action of the tumor upon some visual centre. It seems most probable that the centre affected is that of the corpora quadrigemina; the influence being transmitted through the superior cerebellar peduncles. The high percentage of blindness in the two localities so especially liable would be shown, therefore, to have the same significance. Tumors of the pons and medulla also determine amaurosis otherwise than by choked disc, through direct upward pressure upon the corpora quadrigemina. The direction of the transmission is the same as for the upper (unassociated) nucleus of the motor-oculi nerve, which lies just below the corpora quadrigemina. Out of a total of 51 cases for medulla and pons together, there are 14 cases of amblyopia or amaurosis, or 27 per cent.

To judge from this table we should infer that the chances of amaurosis in brain tumor were exactly equal, whether choked disc existed or not; but that the chances of amblyopia were three times as great without the choked disc as with it. This probably means that if choked disc occur, the impairment of vision which may have been initiated independently of it, by the direct influence of the tumor, will rapidly increase to complete blindness: whereas, without this local complication, the visual defect may for a much longer time, or even altogether, remain partial and incomplete.

TABLE X. LESIONS OF VISION (IN 369 CASES).

Seat.	Total number of cases.	WITH CHOKED DISC.				WITHOUT CHOKED DISC.					OTHER LESIONS OF VISION NOT NOTED.	
		Hemiopia.	Amblyopia.	Amaurosis.	Per cent.	Hemiopia.	Amblyopia.	Amaurosis.	Per cent.	Total per cent. lesions of vision.	Choked disc.	No choked disc.
Centralgyri	....	....	....	1	....	....	....	....	....	....	3	20
Parietal	....	....	....	1	....	....	3	2	....	....	....	12
Frontal	....	....	....	....	....	....	1	....	....	....	....	8
Occipital	....	....	....	....	....	....	....	....	....	....	....	3
Temporal	....	....	....	1	....	....	....	....	....	....	1	....
Entire cortex	56	....	....	3	5	....	4	2	10.5	16	4	43
Centrum ovale	124	....	4	11	12	2 { 1 occipital 1 frontal }	9	13	19	31.5	12	70
Basal ganglia	26	....	....	....	....	....	4	1	19	19	2	18
Cerebral peduncle	10	....	1	....	....	....	2	....	....	....	....	7
Pons	30	....	1	3	13	....	6	....	20	33	2	18
Medulla	21	....	....	....	....	....	1	3	....	19	2	15
Cerebellum	91	....	4	14	19.5	....	9	14	25	45	11	39
Corpora quadrigemina	11	....	2	3	45	....	3	1	36	81	1	1
Total	369	....	12	37	....	....	42	36	....	....	38	254

Total lesions of vision = 127 in 369 cases = 34 per cent.

Hearing, Taste, and Smell.—All these special senses together are less frequently affected than is vision alone. Out of a total of 369 cases of brain tumor, lesions of vision existed in 127, or 34 per cent. But in a total of 561 cases (which include Ladame's), hearing, taste, and smell were altogether affected only in 67, or 12 per cent. In 46 out of these 67 cases the patient suffered from either tinnitus or deafness, the latter rarely complete. In 29 per cent., the tumor was situated in the cerebellum. This fact tends to confirm, if need be, the recent anatomical demonstration, which traces the central fibres of the acoustic nerve to the cerebellum. By far the highest percentage of disturbance of hearing is exhibited by tumors of the corpora quadrigemina. It is singular that reports of tumors of the frontal lobes so rarely mention symptoms indicating lesion of the olfactory tracts. It would seem that an indirect influence or diffused pressure is insufficient to pervert the sense of smell; this is affected only by actual disorganization of the tracts. In a few cases, anosmia, associated with frontal headache, psychic disturbance, and absence of motor or sensory paralysis, has been a valuable symptom which correctly pointed to tumor in the frontal lobes. But anosmia has also been observed with a tumor of the supramarginal convolution. The sense of taste, though controlled by two medullary nerves, usually escapes injury, even with tumors of the medulla. Unilateral paralysis of the acoustic nerve, with correlative deafness, is strikingly frequent in tumors of the cerebellum.

TABLE XI.—LESIONS OF SPECIAL SENSES (561 CASES—369 FOR VISION).

Seat of tumor.	Hearing.	Per cent.	Taste and smell.	Per cent.	Vision.	Per cent.
Cortex (59 cases)	1	1.5	4	7	9	16.0
Centrum ovale (192 cases)	8	4	3	1	39	31.5
Basal ganglia (41 cases)	2	4	..	..	5	19
Peduncle (3 cases)	..	....	..	..	3	....
Corpora quad. (13 cases)	4	30	..	..	9	81
Cerebellum (167 cases)	26	15	2	1	41	45
Pons (56 cases)	3	5	9	16	10	33
Medulla (30 cases)	2	6	3	10	4	19
Total	46	8.0	21	3.5	120	21

Disturbances of Language.—These symptoms were formerly confounded either with symptoms of mental alienation or else with difficult articulation due to tongue paralysis. But their interest and importance have been greatly widened by the modern discoveries that a patient may retain other mental conceptions yet lose that of spoken or written speech; and that the generic aphasic defect may be resolved into several modes: motor aphasia, sensory aphasia, agraphia, alexia. The cerebral region belonging to the faculty of speech occupies an extensive area in the left hemisphere, including the third frontal convolution, the insula, the posterior end of the first temporal convolution, the adjacent parts of the gyrus angularis and occipitalis sinister, together with subcortical association tracts. Tumors in the right hemisphere may also occcasion speech disturbance, when from their considerable size they compress the left hemisphere; or when they cause a distention of the opposite lateral ventricle; or because, as Oppenheim asserts, the right hemisphere participates to a real though subordinate extent in the function of speech.

When a disorder of speech has been a very early symptom of the tumor, it constitutes a valuable means of local diagnosis. Nevertheless speech symptoms not infrequently fail though the tumor be situated in a speech centre; while, on the other hand, any form of aphasia may be caused by tumors at a distance acting on the speech regions by transmitted pressure, or encroaching on them in the course of their growth. With tumors of the central or frontal convolutions the aphasia is sometimes preceded by a bradyphasia; or the patient finds a difficulty in beginning words, or in speaking above a whisper.

When aphasia occurs with tumors of the left occipital lobe, or complicates an alexia or hemianopsia, it is always a sensory aphasia. Tumors of the third frontal convolution are liable to produce spasms of Jacksonian epilepsy in the face, tongue, jaws, and larynx.

From the foregoing analysis of the causation and especial probabilities of diffuse and focal symptoms, it is possible in a given case to answer the two questions: first, Is there a brain tumor present? second, In what part of the brain is it situated?

I. EXISTENCE OF BRAIN TUMOR.—Although a tumor of the brain may develop during either childhood or adolescence, let us suppose it to have begun its growth in an individual of middle age, who perhaps has shown a tendency to tuberculosis. In such a case we can assume that the clinical picture will be somewhat like the following: For weeks or months the patient will suffer from persistent or periodic headache, usually localized at one spot; the pain is peculiarly severe, and is increased by percussion. After a time there will be attacks of vomiting, which sometimes coincide with the most intense paroxysms of pain, and sometimes do not. These attacks, furthermore, seem to bear no relation to the character of the food taken, or to the condition of the digestive organs; they do seem, however, to be dependent upon changes in the position of the body, as, for example, from the recumbent to the upright position. As in the case of sea-sickness, the attacks are sometimes incoercible. They are associated with vertigo; and in turn the vertigo may occur independently of either the headache or the vomiting. It is apt to occur at intervals, and is often chronic in character. After the symptoms which have just been enumerated have lasted for a variable length of time, the patient's gait becomes uncertain; he reels or staggers, or shows a tendency to fall forward or backward. This tendency sometimes increases until complete loss of equilibration renders the patient unable to stand, though he may be entirely free from paralysis. The muscles of one side of the face or of one arm begin to twitch, or even to be agitated by clonic spasms, which either may persist all the time, except during sleep, or else may recur in periodic paroxysms, followed by paresis, gradually increasing to paralysis in the same muscles or in others, *e.g.*, in the arm or leg, after twitching of the muscles of the face. The progress of the paralysis is apt to be interrupted by one or more convulsions, or by attacks of apoplexy or of loss of consciousness; or one of these may usher in the first signs of paralysis, which at the outset may be complete, facial, monoplegic, or hemiplegic. Paræsthesia or anæsthesia is next likely to manifest itself in the paralyzed limbs, or on the side of the face opposite to these. Afterward the symptoms succeed one another in about the following order: alternate paralysis of cranial nerves and extremities; deviations of the eyeballs, isolated or conjugate; dilatation of the pupils, ptosis, much more rarely appearance of Bell's paralysis; occurrence at this time of diplopia, hemiopia, or amblyopia, gradually increasing to complete amaurosis; much more rarely deafness or anosmia, and the discovery of choked disc before or after the development of ocular symptoms; progressively increasing modification of psychic character—at first marked irritability, then impairment of mental powers, loss of memory, apathy or hallucinations, maniacal excitement, and melancholic insanity; before or at the same time with the appearance of this mental change there will be lesions of speech, dysarthria, aphasia, or word-blindness, the two latter often suddenly developed, as after an embolus, the first proportioned to the degree of tongue paralysis and gradual. A patient presenting the foregoing assemblage of symptoms, all progressively increasing, has, with very great probability, a brain tumor. In addition, is to be noted the freedom from pyrexia, and usually from changes in the rhythm of either pulse or respiration. The gradual, sometimes rapid, emaciation, the fact that acute accidents, though often followed by an exacerbation of existing symptoms, or even by the first appearance of new ones, have nearly always been preceded by others which have established themselves insidiously, are circumstances important to the diagnosis.

This being the general picture of the disease, individual cases are framed by the special emphasis of one or more symptoms, or the obliteration of others. The individual peculiarities depend upon (1) the locality of the tumor, (2) upon its rate of growth, (3) upon its complications, and (4), only to a very slight extent, upon its nature.

Peculiarities due to Locality.—These may be divined approximately from such an analysis as has already been given of the symptoms proper to lesions of each given locality. The *a priori* judgment must, however, be modified in view of the tendency of tumors to encroach, in growing, upon territories adjoining their original seat, and also in view of the frequent diffusion of their influence beyond any situation which they may occupy.

The following summary of symptom groups is arranged in the order of characteristicness. It does not correspond to the order of frequency of locality, which, as indicated by the combined tables of Ladame and Bernhardt, would be as follows:

Centrum ovale	192 = 29	per cent.
Cerebellum	167 = 27	"
Cortex	74 = 11	"
Pons	56 = 8	"
Basal ganglia	36 = 5	"
Medulla	30 = 4	per cent.
Corpora quadrigemina	13 = 2	"
Cerebral peduncle	10 = 1	"
Extra-cerebral (including pituitary gland)	71 = 11	"
	649	

But if we consider localities in the order of distinctness with which a tumor in them may usually be recognized, the order would be as follows: cerebellum, pons, cerebral peduncles, cerebral cortex, basal ganglia, corpora quadrigemina, medulla.

LOCAL DIAGNOSIS OF TUMORS.—*Tumors of Cerebellum.*—The most characteristic symptoms occur when the tumor involves the middle lobe. Headache is early, severe, and prolonged, often occipital; vertigo and vomiting are prominent; they may be for a while the only symptoms; epileptiform convulsions of great violence, but not often repeated; choked disc occurs early, preceding amaurosis, but also followed by this; peculiar ataxia, resembling the gait of a drunkard; loss of equilibrium in standing, with tendency to fall forward or backward; often paralysis of one abducens combined with that of opposite rectus internus; absence of other motor paralysis or of general sensory symptoms; loss of patellar reflexes; the intelligence clear till toward the end, when apathy deepens gradually into coma. From pressure upon the pyramids and the cerebral nerves, alternate paralysis is frequent, as are cardiac and respiratory symptoms from pressure on the medulla. From the same cause, singultus, irresistible yawning, salivation. All the nerves at the base of the brain are liable to be irritated and subsequently paralyzed. Varied symptoms in the area of the trigeminal area; pains in the tongue, simulating a gouty neurosis; neuroparalytic keratitis; paralysis of the masticatory muscles; clonic spasms in the territory of the facial and vago-accessorius, in the larynx, soft palate, and pharynx. Unilateral paralysis of the tongue from pressure on the hypoglossal may be added to unilateral paralysis of the acoustic nerve.

When a lateral lobe of the cerebellum is the seat of the tumor, the symptoms are apt to be complicated late in the disease by hemiplegia or hemianæsthesia or both, or by alternate paralysis. Cerebellar tumor is distinguished from pontine tumors by the marked ataxia which precedes the paralysis.

Tumor of Pons, Lower Half.—Uncertainty of gait, rather than ataxia, succeeded by isolated paralysis of third, or sixth, or seventh, or twelfth nerve, not preceded by symptoms of irritation in the muscle which it supplies; or else alternate paralysis, passing into incomplete paraplegia or general paralysis; permanent conjugate deviation of the eyes; amaurosis in a third, choked disc in a fifth, of the cases; entire absence of convulsions; headache, vomiting, and vertigo milder than in cerebellar tumor, or absent, but intelligence affected in half the cases.

Tumor of Upper Part of Pons.—Combination of symptoms proper to cerebellum and pons, as lobe of cerebellum is frequently compressed. Isolated rather than conjugate paralysis of the third nerve; paralysis of the facial on same side as hemiplegia; irritation of the trigeminus, sometimes of motor root, occasioning trismus; or of sensitive root, causing neuralgia on the side opposite to the hemiplegia. Sudden death is especially frequent in tumors of the pons.

In contrast with tumors of the cerebellum, sensory symptoms are manifold in tumors of the pons. The most common is a simple anæsthesia of the extremities on the side opposite the tumor; but sometimes without alteration of the cutaneous sensibility, the muscular and stereognostic senses are impaired. The tracts for the cutaneous sensibility and muscular sense are separated. Besides the Gubler form of alternate paralysis, when the facial is paralyzed on the side of the tumor, the hypoglossal, and extremities on the opposite side, there is occasionally seen a lesion of the trigeminus on the side of the tumor with hemiplegia on the opposite side. Lesion of the motor root causes paralysis of the masticatory muscles with atrophy and electrical degeneration; lesion of the sensory root causes first neuralgia, later anæsthesia. Keratitis neuroparalytica also occurs.

Variations in the form of paralyses are frequent and liable to be misleading. There may be no paralysis of the extremities, but only of cranial nerves, especially the peculiar lesion determining permanent conjugate deviation of the eyes. Or an entirely cerebral form of hemiplegia may exist, or the lesion may limit itself to the nerve nuclei of the pons, paralyzing them without causing motor hemiplegia, but crossed anæsthesia or ataxia, or, through irritation of the pyramidal tracts, crossed intention tremor. Only for a short time does a pontine tumor remain unilateral, but soon it crosses the median line and occasions much complication of the symptoms. The cranial-nerve paralyses become bilateral. The conjugate deviation of the eyes to one side is neutralized by a second on the opposite side, so that the ocular bulbs remain rigidly fixed in the middle line. All four extremities and both hypoglossal nerves become paralyzed. Since the coronal fibres which pass through the pons from both cerebral hemispheres are injured, the medullary nerves dependent upon them—the glossopharyngeal, vagus, and accessorius—are paralyzed, a pseudo-bulbar paralysis results, with difficult deglutition, dysarthria, paralyses of the palate and pharynx, and disturbances of phonation.

As rarer symptoms may be mentioned albuminuria, polyuria, mellituria, and fever.

Tumors of the Cerebral Peduncle and Interpeduncular Space.—The characteristic symptom of this locality is an alternate paralysis in almost all cases (eighty per cent.). The limbs, the facial, and the hypoglossal nerve are paralyzed on the same side, the side opposite the tumor. The motor-oculi nerve is paralyzed by direct pressure on its trunk as it emerges into the interpeduncular space, and therefore on the same side as the tumor. The paralysis is usually total, so that there is unilateral dilatation of the pupil, ptosis from paralysis of the levator palpebræ, and divergent strabismus from paralysis of the internal rectus. Such alternate motor paralyses may exist alone, when the tumor is limited to the pes pedunculi; but if the lemniscus is involved, crossed sensory disturbance, crossed ataxia, or intention tremor from irritation of the fibres of the pyramid will be added to the symptomatology. These symptoms may exist alone without motor paralysis when the tumor begins in the lemniscus. As the tumor grows larger, it crosses the interpeduncular space, causing bilateral oculo-motor paralysis and paraplegia, often symptoms of the pseudo bulbar paralysis. As in tumors springing from the base of the cranium, all the basal cranial nerves may ultimately be involved—trochlearis, abducens, trigeminus, and even facial. Vaso-motor symptoms occur when the substantia nigra is involved.

Tumors of the Cerebral Cortex.—The symptoms vary so greatly, according to the precise part of the cortex which is affected, that each part must be considered separately.

Frontal Lobes.—Notwithstanding the important functions which doubtless pertain to the frontal lobes, a tumor in them not unfrequently remains latent. Bruns denies that psychic symptoms are particularly frequent in frontal tumors; but, according to our tables, they are present in forty-nine per cent. of the cases. One peculiar psychic symptom has been observed, namely, a tendency to crack jokes, the so-called "Witzelsucht" of Jastrowitz. Another characteristic symptom is the ataxia, which has been already mentioned as depending on paresis of the trunk muscles, and which simulates the better known cerebellar ataxia. Tonic cramps of the muscles of the trunk and neck are sometimes noticed,—sometimes a persistent rigidity of the neck. Many symptoms are due to pressure upon neighboring parts. Pressure on the central convolutions will lead to mono- or hemiplegia. Growth downward toward the base of the brain may bring a frontal tumor into direct or indirect contact with an optic nerve, or with the chiasma, resulting in a unilateral choked disc or unilateral nerve atrophy and blindness. Or there may be one-sided paralysis of the ocular muscles, especially the abducens; or a unilateral anosmia; or an exophthalmus if the tumor penetrates the orbit. To these symptoms may be added attacks of Jacksonian epilepsy; motor aphasia; circumscribed tenderness on percussion; lesser degree of headache, but greater tendency to stupor. These concomitant symptoms may serve to differentiate between a frontal ataxia and an ataxia due to cerebellar tumor.

Central Convolutions.—These contain the centres for all the voluntary movements of the body—centres, however, extending into several other areas. Thus the gyrus paracentralis; the posterior part of the first frontal convolution; the anterior part of the superior temporal, the gyrus marginalis (trunk muscles); the foot of third frontal convolution (motor-speech centre); second frontal convolution (centre for movements of head and eyes); neighborhood of facial and hypoglossal centres (movements of vocal chords and jaw muscles). Tumors in this extensive motor zone, therefore, are indicated by most characteristic symptoms of localized spasms and paralyses which occur early in their history. Horsley and Schäfer's experiments on the cortex have permitted further refinements of localization: for the thumb, in the posterior part of the anterior central convolution; for the foot and toe movements, in the posterior central convolution; and on the limits between the leg and arm centres, special centres for the movements of hip and knee. The larynx and the muscles of the trunk receive a double cortical innervation, and thus a unilateral tumor will cause muscular twitchings or Jacksonian convulsions on both sides of the body. As a second consequence of the double innervation, such regions as the eyes and larynx usually escape paralysis in hemiplegia.

According to the most modern view, the motor centres in the central convolutions are also centres for sensibility, and nevertheless sensory symptoms are usually lacking in tumors of the motor zone. Local muscular spasms are, however, frequently preceded by paræsthesias in the affected limbs, constituting a sensory aura. Sometimes the whole attack remains limited to the aura, constituting a sensory epilepsy. Or this again is replaced by a psychic equivalent, a feeling of fear or excessive anguish. When the sensory symptoms are primary, it may be inferred that the tumor occupies the posterior central convolution. The frequent absence of sensory paralyses is explained by a wider distribution of sensory mechanisms, of which a part escape injury in all but the most extensive lesions.

Parietal Lobes.—The symptoms differ on the right and left sides. A left-sided parietal tumor, touching upon the gyrus angularis, is liable to involve the association tracts which pass from the occipital to the left temporal lobe—hence to cause the peculiar disturbance of speech known as alexia. This symptom fails when the tumor is on the right side. From contact with the posterior part of the internal capsule tumors of the parietal region may cause hemianæsthesias; or the motor bundles of the internal capsule may be sufficiently irritated to occasion a hemiataxia.

When, directly or mediately through pressure from a distance, the angular gyrus and optic radiations are involved, there may be ptosis, limitation of the visual field, and homonymous hemianopsia. Loss of the stereognostic sense has been noted as a special symptom in tumors of the parietal lobes.

Temporal Lobes.—Sensory aphasia is the characteristic symptom of tumor of the left temporal lobe. Tumors in this region, on the right side, are apt to be latent. Each auditory centre is connected with both ears, so that deafness is rare; but auditory auræ preceding convulsive attacks, and occurring on the same side, are not uncommon. In tumors of the gyrus hippocampi, and especially of the uncus, epileptiform attacks or their equivalents may be ushered in by the auræ of a bad taste or frightful smell.

Occipital Lobes.—The characteristic local symptom is a crossed homonymous hemianopsia. This symptom belongs to the entire optic tracts from the chiasma to the occipital lobes. In the left occipital, as already mentioned, alexia and optic aphasia are associated with the hemianopsia. Occipital hemianopsia is distinguished from that due to a lesion of a lower part of the optic tract by the absence of various symptoms. There are no hemianopsic pupillary rigidity, no lesion of the basal cerebral nerves, as the motor-oculi or trigeminus; no thalamic symptoms, as hemianæsthesia, hemiathetosis, chorea, or mimetic facial paralysis. Jacksonian epilepsy is usually absent. Cerebellar ataxia may be determined by pressure on the cerebellum, though this is usually protected by the tentorium.

Basal Ganglia or Lower Part of Centrum Ovale.—There is complete hemiplegia often followed by rigidity, thus closely resembling, except in its gradual development, the vulgar hemiplegia of hemorrhage. It is sometimes associated with complete permanent hemianæsthesia, when the tumor is in the posterior part of the hemisphere. It is often complicated late in the disease with symptoms of intraventricular effusion; then there are convulsions, retraction of the head, loss of consciousness, slow pulse, contracted pupils, as in acute hydrocephalus. Localized spasms and monoplegias sometimes occur and are difficult to explain.

When the tumor specially affects the *corpus caudatum*, the symptoms depend on the affection of the internal capsule at its anterior part; there is thus a pure hemiplegia with corresponding convulsions and without sensory symptoms. With tumors of the *thalamus*, hemiplegia is also usual, but is accompanied by hemianæsthesia, pains, ataxic, choreic, and athetosic movements of the extremity opposite the tumor; and finally hemianopsia. Frequently there is a crossed mydriasis, as the nuclei for the internal ocular muscles lie on the lateral wall of the posterior part of the thalamus. The mimetic paralysis of Bechterew—already mentioned as characteristic of thalamic lesions—is also present.

Corpora Quadrigemina.—The chief characteristic of tumors of the corpora quadrigemina is a combination of ocular paralyses with ataxia. This is particularly indicative of this special region when the ophthalmoplegia precedes the ataxia. If the ataxia appear first, there is an equal probability that the tumor is situated in the cerebellum, where tumors are much more frequent—twenty-seven per cent. of the whole number, as compared with two per cent. of tumors of the corpora. With the latter, convulsions are extremely rare; but the percentage of choked disc, amaurosis, psychical defect, is extremely high, and headache and vomiting are both frequent. Pressure on the external geniculate body may cause hemianopsia. Vaso-motor symptoms are uncommon. Scarcely to be separated from the foregoing are tumors of the *pineal gland*. Such tumors may be first manifested by a unilateral or bilateral paralysis of the trochlearis nerve.

Medulla Oblongata.—The symptoms depend on a paralysis of the cranial nerves from the eighth to the twelfth. There are therefore deafness, paralysis, and atrophy of the palate and pharynx, with dysphagia; paralysis of the vocal cords; paralysis and atrophy of the tongue with dysarthria; disturbance in the cardiac and respiratory rhythms. To these characteristic symptoms, due to lesions of nerve nuclei, will be added motor and sensory paralyses as the long cerebro-spinal tracts become involved.

Paralysis of the cranial nerves is almost always bilateral, as the tumor soon crosses the median line along which the nerve nuclei are situated. Acceleration of respiration is followed by dyspnœa, which passes over into Cheyne-Stokes respiration, and death often occurs suddenly through asphyxia. Toward the end of life singultus is frequent, and also a notable rise of temperature. Extensive vaso-motor disturbances occur—diabetes, polyuria. Through lesion of the cerebellar and olivary tracts a cerebellar type of ataxia often develops; and vertigo when the vestibular nerve is involved. Choked disc is not unfrequently absent. An emotional psychosis is not uncommon, and this, with the vagueness of other symptoms, has not seldom led to an erroneous diagnosis of hysteria. This seems still more plausible when the tumor penetrates the fourth ventricle, and causes intermittent symptoms of giddiness, fainting, headache, vomiting, and hysteriform convulsions.

Besides localities in the cerebrum which may be the seat of an intracranial growth, the clinician must always inquire whether the tumor whose existence is suspected does not spring from the cranial bones or the dura mater lining them. Tumors of the anterior, middle, and posterior cranial fossæ excite symptoms which approximately resemble those of the cerebral organs reposing in the same spaces, preceded by symptoms which result from the direct compression of cranial nerves. From distention of the very sensitive dura mater, the headache is peculiarly acute and violent.

Anterior Fossa.—Tumors in this region may break through the roof of the orbit and cause the same symptoms as a primary orbital tumor, namely, unilateral amaurosis, ocular paralyses, trigeminal neuralgias. While the tumor remains limited to the anterior fossa, the olfactory nerve alone is exposed to pressure; and when the tumor compresses the basal part of the frontal lobes, the symptoms are usually vague. Tumors on the left side may press upon the speech centre sufficiently to cause motor aphasia. Frontal ataxia is absent, for the gyrus marginalis is too far removed. The psychic symptom of childishness has sometimes been particularly noted.

Middle Fossa.—The central part of this fossa contains the sella turcica with the pituitary gland. Lesions of the latter are often associated with the peculiar symptom complex known as acromegaly. Apart from this strange disease, the characteristic symptoms of tumor in the middle fossa are due to pressure upon the chiasma and the optic tracts. If the tumor be on the middle line, the optic fibres going to the inner half of each retina will be compressed, causing a bitemporal hemianopsia. This symptom sometimes occurs suddenly, lasts a short time, and vanishes. If the tumor involves one optic nerve in front of the chiasma, there is first unilateral amblyopia, then blindness of the same eye, then, as the tumor extends backward to the chiasma, temporal hemianopsia of the opposite eye, and finally complete blindness.

Yet with these marked visual symptoms choked disc is not unfrequently absent. The fact has been explained by supposing that the tumor obstructs the passage of lymph to the sheath of the optic nerve. Convulsions and vomiting are less severe or altogether absent. Motor and sensory paralyses occur only when the peduncles have become involved; thus after the chiasma symptoms already described, an order of evolution which is highly characteristic. Before the tumor reaches the cerebral peduncles, it will have invaded the lateral region of the sella turcica, and determined the rich assemblage of symptoms dependent on lesions of the motor-oculi and trigeminal nerves: ptosis, neuralgia, anæsthesia or anæsthesia dolorosa; trophic lesions of the skin and eyes; atrophic paralysis of the temporal, masseter, and pterygoid muscles; paralysis of the chorda tympani nerve and sense of taste. If the history of the case be exact the local diagnosis of tumors of the middle fossa can be made with much precision.

Posterior Fossa.—Tumors of this region cannot with any certainty be distinguished from those of the medulla, pons, or lower segment of the cerebellum. Amaurosis or amblyopia exists in one-third of the cases, thus even more frequently than in tumors of the cerebellum. Through a bilateral compression of the cranial nerves or of the pons, tumors of the posterior fossa can determine the typical symptoms of bulbar paralysis, usually preceded by unilateral symptoms in the territory of the trigeminus or acusticus. When the tumor is situated directly over the foramen magnum, all the cranial nerves may escape pressure, but those supplying the four extremities be paralyzed.

Headache is as violent, choked disc as early a symptom as in tumors of the cerebellum.

Parts of Brain in which Tumors are most Frequently Latent.—Complete latency implies absence of all symptoms; incomplete latency implies absence of focal symptoms only. The localities in which the latter condition is characteristically observed are also those in which tumors may most often be completely latent. These localities are: the temporal, occipital, or even, but less easily, the frontal lobes of the cerebral hemispheres, provided the central gyri are not indirectly affected; the parts of the centrum ovale corresponding to these regions, and hence untraversed by fibres from the pyramidal tract; the lateral lobes of the cerebellum, the thalamus opticus, and the lenticular nucleus. Finally, it is possible that in any portion of the brain a tumor may remain latent, providing it grow slowly enough.

DIFFERENTIAL DIAGNOSIS.—The epileptiform convulsions dependent upon cerebral tumor differ little or not at all from those of functional epilepsy. They are, however, often slighter, or at least the loss of consciousness is much less profound. The headache, on the contrary, is chiefly noticeable for its extreme intensity and persistence, in which respect it exceeds even nervous headaches. The vomiting is also noticeable for its violence, and for the absence of any other symptoms of disordered digestion, such as furred tongue, epigastric uneasiness, etc. The diagnosis in regard to these symptoms ultimately depends on their combination, and on their association with paralysis or with psychical symptoms. Conversely, the psychical symptoms of tumor are distinguished from pure mental alienation chiefly by the existence of these physical signs; also by their greater vagueness, which renders precise psychiatric classification difficult or impossible.

It is by no means always easy to decide whether a patient with cerebral symptoms is suffering from a diffused or a focal disease; and in the diagnosis of tumor it is necessary to exclude meningo-encephalitis, progressive general paralysis, chronic basal meningitis, hydrocephalus, cerebro-spinal form of multiple sclerosis, brain abscess, locomotor ataxia.

Tuberculous meningo-encephalitis, which not unfrequently lasts as much as three months, has then a duration not inferior to that of many tumors, and many of the symptoms are identical: violent headache, convulsions, vomiting, neuritis optica, changes of character, monoplegic paralysis, and spasms. In the diffused inflammation, however, these paralyses are transient and variable, a condition sometimes, but rarely, seen in tumor. The disease, moreover, is always attended by more or less fever, by more marked variations in the pupils, by a slow, hard pulse, by obstinate constipation, by retraction of the abdomen, and by vaso-motor symptoms. When a tuberculous tumor is associated with diffused inflammation, it is masked by the symptoms characteristic of the latter.

The appearance of spinal symptoms may decide the diagnosis, which could be still further confirmed by means of a lumbar puncture, and the discovery of pus or tubercle bacilli in the fluid.

A tumor of the medulla may especially simulate *progressive general paralysis* by producing a diffused paresis without distinct paralysis, embarrassment of speech, depression of mental power, headache, and unequal dilatation of the pupils. A tumor, however, is indicated by the occurrence of amaurosis, convulsions, vomiting, localized paralyses; while the diffused disease is characterized by the outbreak of ambitious delirium, and by the peculiar trembling of the lips. There is no choked disc, but rigidity of the pupils and peculiar disturbance of speech.

Tumors of the sella turcica may be closely simulated by *chronic basal meningitis*, which is most frequently situated in exactly the same locality and involves the same nerves. It is distinguished by the occurrence of descending optic neuritis, unattended by symptoms of intracranial pressure. In young children premature closure of the fontanels with blindness would point to meningitis: enlargement of the head to tumor.

Hydrocephalus may also have choked disc, and is usually associated with depressed mental capacity. Slow enlargement of the head in young children belongs either to this disease or to tumor. The rolling down of the eyes and subsequent retraction of the head point to an effusion. Ventricular effusions are not infrequent complications of tumor, especially of tuberculous tumor. General symptoms then predominate over focal symptoms. Bruns and Oppenheim agree that it is impossible to make a positive diagnosis between tumor and acquired hydrocephalus in childhood.

Multiple cerebro-spinal sclerosis may for a time simulate tumor, the disease being characterized by headache, vertigo, disturbances of speech and of vision (diplopia and amblyopia), and by the occurrence of apoplectiform attacks, followed by incomplete hemiplegia. The latter, however, are rare in tumor, but are apt to be frequently repeated in sclerosis. In sclerosis, on the other hand, there is an absence of convulsions and of motor paralyses, except after apoplectiform attacks. Instead, there is a diffused loss of power, with muscular rigidity, absence of vomiting and of choked disc. There are the positive symptoms of nystagmus, scanning or explosive speech, staggering gait and giddiness, spasmodic paralysis of the arms and especially of the legs, finally the characteristic intention tremor of the limbs. Yet tumors of the cerebellum, pons, corpora quadrigemina, and the peduncles may all cause intention tremor through irritation of the pyramidal tracts. In tumors of these localities (except the cerebellum), choked disc is for a long time absent. The difficulties of diagnosis are greatest with children. Extension of the symptoms to the territory of the spinal cord speaks in favor of multiple sclerosis, while a distinctly alternate hemiplegia speaks in favor of tumor. The course of multiple sclerosis is slowly progressive, extending over several years, or is marked by acute attacks separated by intermissions. A modified choked disc may occur for a time, but subsides, and normal vision is preserved, even when optic atrophy is considerable.

Locomotor Ataxia.—It may occasionally be difficult to distinguish the ataxia of cerebellar tumor from that of tabes spinalis. But in the tumor the patient has a staggering or reeling gait, like that of a drunken man, and there is no sign of ataxia in either upper or lower extremities when the patient is in a horizontal position (Althaus). The alterations of sensibility, characteristic of tabes, are absent in tumor, and most of the positive symptoms of tumors are absent in tabes.

Abscess of the Brain.—The symptoms can be quite identical with those of tumor. General pressure symptoms, including choked disc, are less intense with abscess, because this directly destroys brain tissue. Headache, however, is about equally violent in the two cases. Local symptoms are less marked with abscess; one reason is that abscesses are most frequently situated in the latent regions of the brain. If specific regions are affected, characteristic specific symptoms will develop; thus sensory asphasia and hemianopsia in abscesses of the temporal lobe from purulent otitis, or motor paralyses from lesions of the central convolutions after traumatisms.

Fever and chills, when present, are important indications of abscess; but these signs are often absent, and subnormal temperature is rather frequently observed.

The course of brain abscess is usually rapid. But the most important element of differential diagnosis lies in the etiology, for a focus of pus in the brain is never primary, but always secondary to pus elsewhere.

The evolution of abscess is habitually much more rapid, and its progression much more regular than that of tumor. An abscess is always to be suspected when localized cerebral symptoms develop in the course of an otitis media. Extremely chronic cases of this aural affection sometimes pass into an acute exacerbation, during which the cerebral membranes become infected through the roof of the tympanum, through the fenestræ, or through the auditory canal.

Cerebral Hemorrhage.—The onset of the paralysis is sudden, instead of being slow and insidious, and the paralysis is usually at once complete. But the cranial nerves are rarely affected, with the exception of the facial; vomiting, headache, vertigo, and choked disc are absent, as are also mental symptoms after recovery from the apoplectiform shock. Hemorrhage into the meninges, which scarcely ever occurs except in children and old people, does not resemble tumor in any of its symptoms with the exception of convulsions.

Softening.—The diagnosis from tumor is often extremely difficult when the softening is from the beginning chronic in character. Lesions of special senses are much less frequent in softening, and choked disc is rare; so also are lesions of cranial nerves, vomiting, and convulsions; while the headache is less circumscribed and intense. Contractures of paralyzed limbs are more frequent. Psychic alterations are marked, but are of a different character from those of tumor. There is emotional instability instead of irritability, dementia rather than the depression and apathy of tumor.

A diagnosis of the nature of the tumor can rarely be made.

Carcinoma is often indicated by the rapid progress of the symptoms, and by signs of multiple foci successively developing. Perforating tumors are almost invariably malignant—carcinoma, sarcoma, or osteo-sarcoma. The tumor is nearly always primary, and destroys life before it has occasioned cachexia.

Tuberculous tumor often complicates tuberculous meningitis, or is complicated by it. In either case the focal symptoms are much obscured by those of the diffuse disease. When isolated, a tuberculous tumor may be suspected from the youth or scrofulous constitution of the patient.

Gummata.—Their diagnosis principally depends upon the presence of other signs of syphilis. The evolution is relatively rapid, and the invasion of drowsiness and coma may be hastened by the coexistence of diffused endarteritis.

Glioma.—This remains the most probable when the diathetic tumors have been excluded. It not infrequently develops after a blow on the head, and then seems to result from chronic inflammation of the neuroglia.

Intracranial aneurisms occasion symptoms which are indistinguishable from those of neoplasms proper. It is the basilar artery which is most often affected, and the symptoms then resemble those of tumors of the pons.

But all the arteries are liable to be the seat of this lesion. It is said that headache is more diffuse and more intense than with other tumors, while vomiting is less frequent. Sudden attacks of loss of consciousness often occur, due undoubtedly to inequalities in the distention of the tumor and consequent variations in the brain pressure.

Aneurisms of the posterior communicating artery occasion symptoms of motor-oculi paralysis (ptosis, external strabismus, fixed dilatation of the pupil), and finally—the effect spreading to the corpora quadrigemina—amblyopia. When the aneurism is seated on the internal carotid, the sensitive root of the trigeminus may be affected; hence neuralgias or anæsthesia. Aneurisms of the carotid which communicate with the cavernous sinus are characterized by exophthalmia, and a susurrus which is heard when the stethoscope is applied over the eyeball (case Gruening).

The termination of aneurismal tumors is peculiar, being always by rupture and sudden death, with the symptoms of intracranial hemorrhage.

In addition to these various forms of definite brain lesion, a preliminary diagnosis is required between any brain lesion and certain general diseases: arteriosclerosis; neurasthenia, hysteria, idiopathic epilepsy, uræmia, migraine. Choked disc is the most valuable single symptom for the positive decision in favor of tumor, amidst the mass of symptoms which confuse the diagnosis by being common to tumor and to these functional diseases. Bruns claims to have made twenty-two correct diagnoses of the existence and precise locality of a brain tumor; but they were all in one of two groups. First, the central convolutions, posterior and middle fossæ, or the pons. Second, the speech region, the cerebellum, medulla oblongata, corpora quadrigemina, left occipital lobe, occasionally the frontal lobe. Bruns advises to rest satisfied with the diagnosis of the posterior fossa, and only under very favorable circumstances to try to distinguish between the pons, cerebellum, corpora quadrigemina, or base of the cranium.

Rarely is it possible to distinguish between a cortical and subcortical tumor, unless in the cases of alexia due to lesion of the association tracts between the occipital and first temporal convolutions. Collins claims that in a cortical tumor of the motor-speech region, the mental conception of words is destroyed, which is not the case when the tumor is subcortical and destroys only the centrifugal speech mechanisms.

Prognosis.—The prognosis of cerebral tumor is not modified by the diagnosis of either the seat or the nature of the tumor, unless the latter can be shown to be syphilitic. Gummatous tumors sometimes yield with remarkable rapidity to the mixed treatment for syphilis. All others are invariably fatal, but after a longer or shorter lapse of time, and with somewhat different modes of termination. Thus, as has been said, aneurisms terminate by rupture, and death occurs with all the symptoms of cerebral hemorrhage. In the majority of cases the patients die in coma, gradually developed from a condition of apathy and drowsiness. These states are associated with continually increasing brain pressure, which often results in œdema. Sudden death is not uncommon, and is dependent upon inhibition of the cardiac centre. This sudden death may occur as an accident after the most variable duration of the disease; but even the mode of death, which seems to indicate the natural evolution of the morbid process, leaves a most variable time for this to be accomplished. The patient sometimes dies as early as ten or even eight weeks from the appearance of the first symptoms; in other cases these have been prolonged for ten years.

Pathological Anatomy.—The histological structure of many cerebral neoplasms, including aneurisms, does not differ from that of the same growths in any part of the body. Tuberculous tumors, like miliary tubercles, always start from the lymphatic sheaths of the blood-vessels, beginning in a local accumulation of adenoid elements. Gliomata are a species of sarcomatous tumors which are peculiar to the brain. They were described as neuromata, until Virchow demonstrated that they contained no nerve elements, but developed from the neuroglia. The glioma may consist almost exclusively of cells, and is then called a medullary glioma; or it may contain a large amount of connective tissue, which either remains soft and of the myxoma type (myxoglioma), or becomes hard, fibrous, or even cartilaginous (fibrous glioma). Finally, some among these tumors are so rich in vessels as to have acquired the name telangiectatic gliomata. All develop from the neuroglia. The tumor appears as a grayish mass, becoming pink or red as vessels develop in it. If these are numerous, apoplexies may take place into the substance of the tumor. The three forms of malignant tumor of the brain are sarcomata, carcinomata, and melanoid tumors. The first are closely related to the gliomata, arising like the medullary variety of the latter; the chief difference consisting in the greater size of the cells and the larger amount of intercellular substance. Cancer of the brain is nearly always encephaloid, primary, and not infrequently congenital. The growth is rapid, and the size ultimately attained by the tumor is in inverse proportion to the vital importance of the part of the brain in which it is seated. Enucleation of the tumor is impossible. Cancer of the upper part of the cerebral hemispheres not infrequently perforates the dura mater, and even the skull. Conversely, cancer of the eyeball, usually melanotic, constantly tends to penetrate the brain.

Melanoid tumors are forms of carcinoma in which the tissue is infiltrated with pigment. Their most frequent seat is the eyeball, the pigment being derived from that of the choroid.

Hydatid cysts are found in the brain, but they usually remain latent, especially if small and multiple. Other varieties of cyst are not infrequently formed by hemorrhagic effusion, by softening of brain tissue from extensive necrobiosis, or by the softening of myxomatous tumors.

COMPLICATING LESIONS.—With glioma, congestion and hemorrhage in the vicinity of the tumor are the most frequent complications, the latter often being the cause of death. The tissue around the tumor is often the seat of an inflammatory softening. Effusion into the ventricles is often caused by compression of vessels which return blood from the choroid plexus. Such effusion is common with tubercle, and then may depend on granular thickening of the ependyma.

A zone of non-inflammatory softening surrounds most tumors. It depends upon necrobiosis of nerve tissue, from localized obstruction to the circulation and œdema. When this softening is extensive, functional regions quite different from those actually occupied by the tumor become involved. This circumstance, as has often been shown, by complicating the symptoms often materially obscures the diagnosis.

When the fibres of the pyramidal tract have been affected by the tumor, descending degeneration or secondary sclerosis may set in, and even reach the lateral columns of the cord. This is, however, much less common than after hemorrhage; and, correlatively, late rigidity is correspondingly rare. Conversely, the appearance of rigidity in limbs paralyzed from the effects of a cerebral tumor often indicates that hemorrhage has been excited in its vicinity.

TREATMENT.—There is no radical medical treatment except for gummata, and for these the mixed treatment sometimes yields brilliant results.

In 1884 an epoch-making event occurred. Two English surgeons, Bennett and Godlee, attempted to remove a cerebral tumor by a bold surgical operation. Between 1884 and 1893 this operation was performed eighty-five times. These eighty-five cases are recorded and analyzed in a table published in the Supplement to the REFERENCE HANDBOOK in 1894, to which, for details, the reader is referred. Out of the eighty-five operations twenty-four resulted in recovery, about one-thirteenth. Between 1893 and 1899 many new cases of operation are recorded in tables published by Starr (Trans. Med. Soc. New York, 1896) and also by Knapp (Boston *Med. and Surg. Journ.*, October 12th, 1899). These collections are included in the list tabulated below, but to them have been added a number derived from other sources. The total number of cases in which the operation has been performed since 1893 is one hundred and thirty-eight. These new cases have not been analyzed, but the model for their analyses is offered on pp. 122 *et seq.* of the Supplement (vol. ix.).

Prefrontal.

1. Carle: Revue de chirurgie, February, 1899.
2. Devic and Courmount: Revue de méd., April, 1897.
3. Obiet: Il Policlinico, ii., 6, 1895.
4. Thomas and Keen: Am. J. Med. Sc., November, 1896.

Central.

5. Abbe: Presse médicale, November 19th, 1895.
6. Abrams and Tait: Occidental Med. Times, June, 1896.
7. Annandale: Edin. Med. Journ., i., 899, 1894.
8. Armstrong: Montreal Medical Journal, May, 1896.
9. Ballance: Med. Chir. Trans., lxxix., 167, 1896.
10. Beevor and Ballance: Brit. Med. Journ., i., 5, 1895.
11. Bonhoeffer: Monats. f. Psych., April, 1898.
12. Braymer: Charlotte Med. Journ., November, 1896.
13 Bremer and Carson: Amer. Journ. Med Sci., February, 1895.
14 Broca and Maubrac: Arch. gén. de méd., February, 1896.
15. Bruns: Neurolog. Centralbl., xiv., 125.
16. Cornil and Doyen: Bull. de la soc. anat. de Paris, November, December, 1897.
17. Crowley: Tr. Med. Soc., California, xxviii., 197, 1898.
18. Czerny: Münch. med. Wochenschr., No. 11, 1896.
19. Dallas and Mongeri: Gaz. méd. de l'Orient, 1897.
20. Dana and Conway: N. Y. Med. Journ., i., 779, 1895.
21. Doyen: Arch. f. klin. Chirurg., lvii., 876, 1898.
22. Dreyfus: Lyon médicale, lxxxviii., 195, 1898.
23. Duncan and Maylard: Glasgow Med. Journ., April, 1897.
24. Elliott: Boston Med. and Surg. Journ., June 5th, 1897.
25. Eskridge and Parkhill: Med. News, August, September, 1896.
26. Friedländer: Wiener klin. Wochenschr., January 21st, 1898.
27. Gibson: Edinburgh Med. Journ., February, 1896.
28. Graser: Arch. f. klin. Chir., l., 901, 1895.
29. Grisson: Neurolog. Centralblatt, xvii., 1138, 1898.
30. Hassler: *Ibid.*, xvi., 1068, 1897.
31. Hirschl: Neurolog. Centralblatt, xv., 609, 1896.
32. Hitzig: Therapeut. Wochensch., Nos. 19, 20, 1896.
33. Horsley: Lancet, 1894.
34. Kappeler: Deutsch Zeitsch. f. Chir., xl., 500, 1895.
35. Krauss: N. Y. Med. Journ., 1898.
36. Krönlein: Beiträge z. klin. Chir., 1895.
37. Lanphear: Journ. Amer. Med. Assn., April and May, 1895.
38. Maneau: Archiv. méd. d'Anges, 1212, 1897.
39. Meyer: Annals of Surgery, 1898.
40. Murray: Lancet, March 16th, 1895.
41. Mya and Cadwillia: Il Policlinico, March, 1894.
42. Nason: Lancet, May 25th, 1895.
43. Nedwill: Lancet, i., 1466, 1898.
44. O'Hara: Intercolonial Quarterly Journ., 1874.
45. Oliver and Williamson: Brit. Med. Journ., November 26th, 1898.
46. Pel: Berlin. klin. Wochenschr., January 29th, 1894.
47. Putnam and Richardson: Boston Med. and Surg. Journ., February, 1899.
48. Riezner: Deutsche med. Wochenschr., 1894, p. 497.
49. Roth: Deutsche med. Wochenschr., No. 25, 1895.
50. Schlesinger: Wiener klin. Wochenschr., No. 25, 1895.
51. Sick: Deutsche med. Wochenschr., No. 2, 1897.
52. Schnitzler: Centralbl. f. d. ges. Therapie, xvi., 65, 1898.
53. Schwartz: Bull. Soc. de Chirurgie, xxi , 221, 1894.
54. Shaw and Bush: Bristol Med. and Chir. Journ., ii., 99, 1895.
55. Sinkler: Trans. Amer. Neurolog. Assn., 1896.
56. Stratton and Crowley: Pacific Med. Journ., xli., 282, 1898.
57. Sweeney: Northwestern Lancet, xiv., 261, 1894.
58. Syme: Australasian Med. Journ., 1895.
59. Tauber: Archiv di Psich. Russ., xxvii., 1, 1896.
60. Von Wayenburg: Psych. en Neur., Hadem, ii., 109, 1898.
61. Vierordt and von Beck: Fortschr. d. Med., p. 495, 1894.
62. Washburnand Lane: Trans. Clin. Soc., London, xxx., 154, 1897.
63. Webster: Canada Practitioner, xx., 813, 1895.
64. White: Lancet, ii., 1280, 1894.
65. Wiener: N. Y. Med. Journ., October 15th, 1898.
66. Wood and White: University Med. Mag., January, 1895.
67. Ziehm: Zeitschr. f. prakt. Aerzte, No. 5, 1898.
68. Ziehl and Roth: Deutsch. med. Wochensch., No. 19, 1897.
69. Mann: Monatsschrift für Psychiat., iv., 369, 1898.
70. Bonhoeffer: Monatsschrift für Psychiat., iii., 497, 1898.
71. Haasler: Arch. für Psychiat., xxx., 660, 1898 (recovery).
72. Chipault: Gaz. des hôp., lxxi., 416, 1898.
73. Kosinski: Medycyna Warozowa, xxvi., 1–31, 1898 (recovery).
74. Armitage: Lancet, ii., 1395, 1898 (death).
75. Mills and Keen: Journ. Nerv. and Mental Dis., xxvii., 244, 1900.
76. Steffen: Med. News, lxxvi., 175, 1900.
77. Sweeney: Northwestern Lancet, July 15th, 1894 (recovery).
78. Pel: Gaz. des Hôp., January, 1895.
79. V. Bramann: Langenbeck's Archiv, Bd. 51, Heft 1 (Haeckel, Monatssch.).
80. Colman and Ballance: Lancet, March 21st, 1896 (*ibid.*).
81. Gibson, Lancet, December 14th, 1895 (*ibid.*).
82 Krönlein: Bruns' Beiträge, Bd. xv., H. 1 (*ibid.*).
83. Krognis: Revue de Chirurgie, 1896 (*ibid.*).
84. Thomas and Keen: Amer. Journ. Med. Sci., 1896.
85. Pearson: Dublin Journ. Med. Sci., cii., 484, 1896.
86. Bieganski: Medycyna Warozowa, xxiv., 1896.
87. Albert: Wien. med. Wochensch., xlv., 1895.
88. Keen: University Med. Mag., viii., 1895.
89. Oliver: Journ. Amer. Med. Assn., xxvi., 1896.
90. Pel: Gaz. des hôp., January, 1895, or Bd. iv., January 29th, 1894 (Starr).
91. Steele: Journ. Amer. Med. Assn., January, 1894 (Starr).
92. Dana: Journ. Mental and Nerv. Dis., June, 1895 (Starr).
93. Nixon: Trans. Acad. Med. of Ireland, vol. xii., 1895 (Starr).
94 Grasser: Deutsche Med. Zeit., 1895.
95. Gaykiewicz: Neurol. Centralbl., 1895.
96 Bruns: Neurolog. Centralbl., p. 125, 1895.
97. Horsley: Clinical Journal, February 13th, 1895.
98. Starr and McBurney: N. Y. Med. Record, February 1st, 1896.
99. Starr: Tr. Med. Soc., New York, 1896.
100. Starr: Amer. Journ. Med. Sci., 1894.
101. Starr: Amer Neurol Assn., 1897.
102. Starr: Tr. Med. Soc., New York, 1896.
103. Starr and Keen: Amer. Journ. Med. Sci., November, 1896.
104. Starr and Weir: Tr. Med. Soc., New York, 1896 (op. 1896).
105. Starr and McBurney: Tr. Med. Soc., New York, 1896.
106 Starr: Brain Surgery, 1894.
107 and 108. Starr and McCosh: Tr. Med. Soc., New York, 1896.
109. Starr: Medical News, lxxi., 170, 1897.
110. Cabot: Boston Med. and Surg. Journ., cxxxvi., 1897.
111. Gessler: Med. Cor.-Bl. d. Würtemb. Aerzt. Stuttg., lxvii., 1897.
112. Robertson: Nashville Journ Med. and Sci., lxxxii., 1897.
113. Clark: Glasgow Med. Journ., xlviii., 1897.
114. Bair: Brit. Med. Journ., ii., 1082, 1897.
115. Washbourne: Tr. Clin. Soc., London, 1896.
116. Delorme and Schwartz: Bull. Soc. de Chir., 1895.
117. Ruheman: Deutsche med. Wochen., xxii., 355, 1896.

Parietal.

118. Von Beck: Beiträge z. klin. Chir., xii., 1.
119. Colman and Ballance: Tr. Lond. Clin. Soc., xxix., 1896.
120. Eskridge and Parkhill: Med. News. July 11th, 1896.
121. Fitzpatrick: Australasian Med. Gaz., p. 581, 1894.
122. McCosh: Amer. Journ. Med. Sci., May, 1896.

Temporal.

123. Baer and Nicoll: Brit. Med. Journ., October 16th, 1897.
124. Nicoll: Lancet, October 29th, 1898
125 Stewand: Northwestern Lancet, 1897.

Cerebellar.

126. Collins and Brewer: Med. Record, 1897.
127. Gibson: Edin. Med. Journ., February, 1896.
128. Guthrie: Practitioner, lxi., 69, 1898.
129. Moran and Kerr: Virginia Med. Semi-Monthly, July, 1897.
130. Munn: International Journ. of Surgery, 1895.
131. Murri: Lancet, January 30th, 1897.
132. Parkin: Brit. Med. Journ., 1896.
133. Pershing: Medical News, March 26th, 1898.
134. Stewart and Annandale: Edin. Hosp. Rep., 1895.
135. Steele: Chicago Clin., xiii, 1–7, 1900 (death).
136. Hirmanidas: Neurolog. Centralbl., 1895.
137. Stewart and Annandale: Edin. Hosp. Rep., 1895.
138. Fisher: Tr. Med. Soc., New York, 1896.

To these may be added the following list of cases, also collected by Knapp, in which an operation was attempted, but removal of the tumor found to be impossible:

Aldibert: Revue de chir., p. 158, 1895.
Beck: In Auvray, pp. 359, 360, 361.
Bruns: Brain Tumors.
Carson: Annals of Surgery, xxviii., 328.
Chipault: Gaz. des hôp., lxxi., 557, 1898.
Collins: Tr. Amer. Neurol. Assn., 1895.
Dinkler: Neurolog. Centralbl., xvi., 611, 1897.
Eskridge: Denver Med. Times, June, 1896.
Fisher: N. Y. Med. Journ., April 16th, 1898.
Gardiner: Amer. Journ. Med. Sci., May, 1899.
Hermanides: Operative behand. van husengezwellen, 1894.
King: Chicago Clinical Review, April, 1897.
Krauss: N. Y. Med. Journ., July 30th, 1898.
Lanphear: Journ. Amer. Med. Assn., April 28th, 1895.
Rose: Medical Press and Circular, i., 175, 1894.
Rossolimo: Arch. f. Psych., xxix., 528, 1897.
Schultze: Deutsch. Zeitsch. f. Nervenheilk., ix., 217, 1896.
Sonnenburg: Berlin. klin Wochenschr., p. 939, 1894.
Starr: Med. Record, l., 145, 1896.
Starr: Brit. Med. Journ., October 16th, 1897.
Stieglitz: Amer. Neurol. Assn., 1895.
Taylor and Elliott: Boston Med. and Surg. Journ., 1896.
Winkler: Bijdrage tot de Husenchirurgie.

The later operations have not been able to modify the percentage arrived at in 1893, for in 1897 Bruns, after a somewhat complicated calculation from statistics, concluded that the number of successful cases was not higher than six in a hundred.

Bruns, however, does not hesitate to advise the operation whenever the tumor can be exactly localized in an accessible part of the brain. For even when it shall have been found irremovable, the operation may serve to relieve the frightful pain, or even to arrest the progress of choked disc toward blindness, and it seems to be the undercurrent of Bruns' thought that in a disease like brain tumor, which he calls the most frightful of all diseases for the suffering it entails, it were really better that the patient should die in the attempt to secure relief, than that he should be abandoned to his suffering.

Quincke's lumbal puncture has been practised for the purpose of lessening intracranial pressure, but has often failed, perhaps from obstruction in the communications between the brain and spinal cord. The puncture has several times been immediately followed by death.

The intellectual, philosophic, and even romantic interest attaching to the operations for brain tumors much exceeds their actual practical importance. The attempt has been made to estimate this from analysis, not only of the operations which have been performed, but also of the fatal cases of brain tumors on record, not operated, but submitted to post-mortem examination. The latter has shown that a very large proportion would have been inoperable, either because a local diagnosis could not have been made, or because the locality, though diagnosed, was inaccessible; or because the tumors were multiple or malignant; or, finally, because they were too large for extirpation. The last objection can often be met by the observation that an early operation might have proved successful, though by delay the tumor had grown beyond the bounds of surgical possibilities. This observation, however, holds good for tumors in any part of the body.

Tuberculous tumors—the most common variety by far in childhood—are frequently multiple, either at the time of operation or by recurrence shortly after; and are then, of course, unfavorable for operation. For extremely malignant tumors (carcinoma) the prognosis is naturally as hopeless when the growth is situated in the brain as when it exists in other organs. On the other hand, sarcomata, when primary, have not unfrequently been removed with success.*

A table quoted by Keen, in the article on *Brain, Surgery of*, in this volume (p. 416), shows the relative proportion of different varieties of brain tumors in a total of 580 cases collected by Hale White and Bernhardt. Nearly a quarter of all (23 per cent.) were tuberculous, only 4 per cent. were carcinomatous. In 22 per cent. of the cases cited the nature of the tumor is not stated.

Hale White estimates that only 9 of his 100 cases could be considered as operable. No tumor, even the most benign, could be considered operable which is situated at the base of the brain, or in the cerebral axis (Starr), which is widely infiltrated, or which, as already noted, is multiple. Out of 300 brain tumors in children collected by Starr, one-third were in the cerebral axis. Tumors of the cerebellum are fairly accessible, but operations upon them have proved very much more dangerous than operations upon the cerebrum. The space for operation is much narrower; precise localizing symptoms are much less distinct and frequently fail altogether. On the other hand, the general symptoms are especially severe, owing to the excessive intracranial pressure; and this same condition endangers the operation by causing the brain to bulge through the opening. The close proximity of the affected part to the most vital organs of the cerebro-spinal axis renders shock imminent. The tumor is very frequently tuberculous, and finally optic neuritis has nearly always reached an advanced stage before the operation is undertaken, so that when, by exception, the patient has survived the operation, he has remained blind.†

Out of the 300 cases of tumor in children, 96 were situated in the cerebellum. This single fact suffices to establish a relatively unfavorable prognosis for brain tumors in childhood.

In this same list were found 56 cases of tumor of the cortex and centrum ovale, localities favorable for operation; 16 of these, however, were not correctly diagnosed, and therefore could not have been operated on, even if the operation had been suggested.

Out of the 40 which remain, localizing diagnosis would have been impossible in 21, though the autopsy showed that in some of them an operation would have been possible. In 19 cases the tumors were in the central convolutions, or in the subjacent centrum ovale, and in 13 of these local spasm followed by paresis made the precise diagnosis sufficiently clear. In the remaining 6 the locality was established by the symptom hemianopsia. The author estimates, however, that in only 16 of these cases could an operation have been undertaken with much hope of success, and as 10 of these were tuberculous, the number of cases in which even this new and heroic remedy offered hope of complete recovery was reduced to 6 out of a total of 300.

The statistics for adults, as regards localization, differ somewhat from the above. A table of 644 cases, compiled from the cases of Ladame and Bernhardt, shows the different localities in which the tumor was found. It was situated in the—

Centrum ovale in	192 cases	= 29 per cent.
Cerebellum in	162 "	= 27 "
Cortex in	74 "	= 11 "
Pons in	56 "	= 8 "
Basal ganglia in	36 "	= 5 "
Medulla in	30 "	= 4 "
Corpora quadrigemina in	13 "	= 2 "
Cerebral peduncle in	10 "	= 1 "
Extra cerebral in	71 "	= 11 "

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* In the case reported by Weir and Amidon the cerebral symptoms occurred after the patient had already been operated upon for sarcoma of the neck (Annals of Surgery, June, 1887).

† The symptom of choked disc, when present, has long been considered more nearly pathognomonic than any other of cerebral tumor. Seguin has, however, recently declared that many cases of enormous

This table can be compared with Starr's, as follows:

Tumors situated in	Children.	All cases.
Cerebellum	96 cases = 32%	162 cases = 27
Cortex and centrum ovale ..	56 " = 18	266 " = 41

Thus consideration of the prevailing situation of brain tumors alone would seem to justify Bergmann's dictum, that the field for successful operation is very narrow, the reverse of what can be now affirmed of trephining for brain abscess. Examination of the 85 cases in which operations have been performed between 1884 and 1893 gives a more favorable view. The record shows that there were 39 successful operations against 46 unsuccessful cases, and one trephining to relieve intracranial pressure. These were performed in all parts of the world, even British Guiana having contributed a successful case in 1888 (Rannie, *British Medical Journal*, 1888). The following table summarizes these results. "Successful" implies that the tumor was found and removed, that the serious symptoms subsided, and that the patient lived more than two months, or even recovered completely. "Unsuccessful" refers, not only to the death of the patient from the immediate consequences of the operation, but also to the impossibility of completing this, either because the tumor was not found at the locality supposed, or proved too large or too deeply seated to be completely removed; finally to the speedy recurrence of the tumor so as to cause the death of the patient in a short time, notwithstanding the immediate success of the operation.

Successful..		39
Unsuccessful:		
Tumor not found	20	
Tumor not removed..............................	10	
Death from operation or speedy recurrence of neoplasm	16	46
		85

In 1888 Dr. Keen wrote (REFERENCE HANDBOOK, *Brain Surgery*) that the percentage of mortality was 35 per cent. This calculation was based upon the 17 operations which had then been performed, with 6 recoveries, and included among them one case (Heath, *Lancet*, 1888, Case 27 of table), which we have placed among the unsuccessful cases, because, although the patient survived the operation and was relieved, the tumor was too large for removal. The percentage of successes (11 cases out of 17) was nearly 65. To-day, the larger number of cases yields as succcessful about 46 per cent., as failures nearly 54 per cent. The less favorable result is not surprising, for the operation has been attempted under a much greater variety of circumstances, so that a greater number of unfavorable conditions have been encountered. For this reason the estimate of the operation has varied in the same way as did that for tracheotomy. This operation on its first suggestion excited unbounded enthusiasm, until experience showed how numerous conditions of failure were inherent in the disease for which the operation was performed, and which could not be overcome by any degree of perfection in its surgical technique.

The precision is surprising with which small tumors have sometimes been localized for removal. In Seguin and Weir's case (No. 24) the neoplasm was only the size of an almond, and lay an inch below the surface. In another case, however, reported by Seguin, a glioma one-half inch in diameter escaped detection. It was found at the autopsy at the locality diagnosed, under the motor centre for the left leg, but its consistency so resembled that of the brain tissue that it could not be differentiated (Case 63). The writer remarks that an operation may be undertaken too early on the brain—*i.e.*, before the tumor has grown sufficiently large to be appreciable, even although it may have occasioned pathognomonic symptoms.

In 19 other cases in which the tumor was not found, the reason for the failure was quite different. In Keetley's case (41) the pons was found enlarged to three times its natural size by an infiltrating glioma. The only localizing symptom presented had been a slight internal strabismus of the left eye (paresis abducens). This fact should have suggested a pontine, and consequently inoperable tumor, as also the fact that the knee-jerks were exaggerated, while absence of paralysis, and existence of vomiting, giddiness, and staggering pointed to a tumor of the cerebellum.* With the latter, however, the knee-jerks are habitually diminished, and this special combination of negative and positive signs should suggest a lesion of the pons, in spite of the absence of many of its characteristic paralyses. The patient, a child of seven, who had had a fall fourteen days before the onset of the symptoms, had an attack of collapse followed by a subnormal temperature just before the operation, another circumstance pointing to the pons. An exploratory operation was made through the left squamous bone, but nothing was found, and the child died two days later.

In Pilcher's case (31) there was a scar (after an injury) situated over the left angular gyrus, and the skull was trephined at this point. The patient had marked mental impairment, epileptic attacks, beginning in a conjugate deviation of head and eyes to the left, and tonic hemispasm on the right side. Schäfer (*Brain*, April, 1888) claims that excitation of the brain near the angular gyrus produces conjugate deviations of the eyes to the opposite side. The centre for such deviation is placed by Horsley at the posterior extremity of the middle frontal gyrus; and the autopsy in this case would seem to confirm that localization. A glioma was found on the left side, in the occipital lobe, but extending forward as far as the frontal lobe. The island of Reil was softened. The mental impairment, taken together with the conjugate deviation of the eyes, pointed to the frontal lobes, where also the headache was situated. Nothing indicated the occipital lobe, and at the angular gyrus nothing was found. In Sciammana's case (3) also the patient was trephined, unsuccessfully, at the seat of an injury to the head in the right parietal region. The tumor was a glioma, lying in the right centrum ovale and extending from the right inferior cornu to the corpora quadrigemina. Crossed paralysis had existed, left hemiplegia, followed by right oculo-motor and facial paralysis. This is not explained by the autopsy.

Kerr's operation (58) is the third on the list misled by a scar. The indication was the more plausible because the scar was situated over the upper part of the left fissure of Rolando, in a patient suffering with hemispasm and hemiparesis. A glioma was found in the left corpus striatum and optic thalamus. This is the only case on the list in which a tumor in this situation had simulated a cortical tumor.

In Knapp's second case (65), the trephine was applied over a tender spot in the right temporal region, although there were well-marked symptoms of a cerebellar tumor. After death, ten weeks after the operation, the tumor was found in the left lateral lobe of the cerebellum. In this case the left knee-jerk was absent, and there was slight paresis of the left hand, symptoms which, together with the characteristic symptoms of tumors, might have sufficed to indicate the cerebellum.

In seven other cases an erroneous diagnosis was made of tumor of the cortical motor centres (Fraser, Hammond, Amidon, Stokes, Walker, Dobson, Twynam), and in one (Beach) of tumor of the frontal lobe pressing on the central convolutions (Cases 5, 7, 8, 51, 55, 73, 80).

In Fraser's case (5) the localizing symptoms were right hemiplegia and contracture, indistinct speech, amnesic

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tumors do not present choked disc, and, on the other hand, this ocular lesion occurs in persons who have no intracranial disease. "Indeed, in my experience as regards tumors of the hemispheres, the rule is that the optic nerves are normal" (Boston Medical and Surgical Journal, February 5th, 1891).

* The knee-jerks are usually diminished in tumors of the cerebellum, whereas they are exaggerated in tumors of the pons. This may be a useful detail in distinguishing between these two lesions, whose symptoms often resemble each other.

aphasia, agraphia. The error depended on the duplicity of the lesion. There was a tumor in the middle of the right ascending parietal convolution, and another in the left temporal lobe involving the ascending convolutions. The amnesic character of the aphasia really pointed to the left temporal lobe rather than to the neighborhood of Broca's convolution. It is difficult to understand the failure in Hammond's case (7), as the autopsy revealed three cysts in a line in the anterior central convolution precisely where the lesion had been diagnosed. In Amidon and Weir's case (8) the tumor was found in the cerebellum at the autopsy, although the patient had had left hemispasm and paralysis of the left arm. Two circumstances, however, pointed to the cerebellum—with the left-sided paralysis coexisted a paresis of the right arm, thus a bilateral motor defect, and there was also optic neuritis on the left side. Stokes' case (51) shows, as the author remarks, that the motor centre for the leg extends farther back than is usually assumed, or else that pressure transmitted from a distance may cause the same symptoms as a lesion at the centre. A spindle-celled sarcoma was found in the parietal lobe, just behind the leg centre, and being of the same consistency as the brain, could not be distinguished.

In Walker's case (55) the symptoms were very confusing. Staggering seemed to indicate a cerebellar tumor, as did also the vertigo and vomiting. But a marked mental defect pointed to the frontal lobes, and motor aphasia to a lesion on the left side. On the other hand, left hemispasm and hemiplegia were to be referred to the right side of the brain, and hemorrhage and an offensive discharge from the right ear seemed to localize the disease more precisely near the petrous bone. Paresis of both hands pointed to the cerebellum; exaggeration of the left tendon reflex, on the contrary, confirmed the indications offered by the left hemiplegia. An exploratory operation was performed over the left ascending frontal with negative result. At the autopsy a cystic mass was found at the left of the sella turcica, springing from the apex of the petrous bone. The record leaves unexplained why this should have been associated with discharge from the right ear.

Dobson's case (73) exhibited an apparently exquisitely precise symptom, namely, twitching attacks in left arm, beginning in thumb and first finger, with sensory aura in same parts. Horsley has located the thumb centre just behind the middle of the ascending parietal convolution, and a signal symptom in Jacksonian epilepsy, initiated at this point, has several times guided to an exact diagnosis. But in this case the centre was evidently irritated by pressure from a distance. There were multiple cerebral tubercles in the right hemisphere. This is the second case of multiple tumor on the list.

In Twynam's case (80) the tumor seems to have escaped detection, partly because it lay too far below the surface in the medullary substance, partly because, as in Stokes' case, the tumor, though pressing on the central convolutions, lay behind them, in the parietal lobe. Besides the hemiparesis there was some loss of sensations, and this symptom, as well as the loss of muscular sense, seems to point to the parietal lobe rather than the central convolutions. Another fact in the same sense was the incomplete nature of the paralysis. The tumor found on autopsy was very large, 68 by 57 millimetres, extending from the Rolandic fissure to the parieto-occipital, and bulged into the roof of the lateral ventricle.

In Beach's case (52), finally, a tumor was diagnosed in the left frontal lobe, pressing on the lower part of the central convolutions. The first local symptom had been a motor aphasia, followed by tremor, then twitching of right hand and eyelid, then paresis of right hand. The tumor was found at the supposed level, but, as in Cases 51 and 80 (Stokes and Twynam), it lay in the parietal lobe behind the motor convolutions and between the posterior ascending branch of the Sylvian fissure and a small sulcus anteriorly which separated it from the ascending parietal convolution. There were no sensory symptoms to aid the diagnosis.

In Wille's case (25) a tumor of the left parietal lobe was diagnosed, but the diagnosis was guided by the existence of a swelling over the left parietal bone. Only after this had been incised did right hemiparesis appear, including the facial nerve. In a second operation subdural pus was evacuated, but no tumor was found. At the autopsy was discovered a tumor the size of a pigeon's egg in the posterior part of the left paracentral lobule, extending into the upper part of the ascending parietal convolution. Also, and this makes the third case of multiplicity, a second tumor was found in the middle of the ascending parietal convolution. In two other cases on this list the tumor lay in the cerebellum. In Wyman's case (53) it had been diagnosed in the sella turcica, because, in addition to the general symptoms, the patient had a divergent squint (paralysis of the motor-oculi), anosmia, and slight movement of rotation at the beginning of the convulsive attacks. There was great muscular weakness, but neither hemiplegia nor staggering. A tumor three-quarters of an inch long was found in a cavity hollowed out in the left hemisphere of the cerebellum. All the ventricles were distended with fluid. The great frequency of cerebellar tumors might, it would seem, have decided the surgeon to operate, if at all, in their locality. But instead of this he trephined the frontal bone above the supra-orbital ridge and passed a probe over the orbital plate to the sella turcica with necessarily negative result.

In Springthorpe's case (47) a cerebellar tumor was correctly diagnosed, and several symptoms pointed to pressure on the right lobe of the cerebellum. In the fits there was conjugate deviation of the head and eyes to the right side; the right ear was moderately deaf, and the patient fell backward and to the right side. An opening was made over the right lobe of the cerebellum, clear serous fluid escaped, but no tumor was found. At the autopsy a glioma with a central cavity was found to occupy the middle lobe of the cerebellum. All the ventricles were full of blood-stained fluid. The main pressure was upon the right side.

The last case was reported by Gray and operated by Wyeth (84). The exact locality of the tumor was correctly diagnosed, but it lay one-quarter inch below the surface (as had been expected from the absence of convulsions), and the consistency so closely resembled that of the medullary brain tissue in which it was embedded that an exploring needle passed through it without detecting its presence, and it was discovered at the autopsy with difficulty, and only by careful slicing of the brain.

Nearly all the cases in which the tumor was not found at the site of operation proved fatal, the operation seeming to accelerate the natural march of the disease. One patient, however (Amidon and Weir), survived ten weeks, another (Dobson) a month. Four cases illustrate the now accepted rule, that a scar, and still less a tender point on percussion, must not be selected as a site of operation, unless focal symptoms point to the same locality.

In the five cases of cerebellar tumor a retrospect of the symptoms, after the autopsy, makes them seem more significant than they had appeared before the operation. Cases 47 and 53, as do many other cases which have not been operated on, show the impossibility of distinguishing with certainty whether a tumor of the cerebellum be situated in its lateral or its middle lobe. Nothnagel's law of the frequent latency of tumors of the lateral lobes should always incline the diagnosis in favor of a central lesion, unless lateral symptoms are very well marked. The danger of hemorrhage, however, from trephining over the centre of the cerebellum, *i.e.*, of the sinus, is very great, and, on the other hand, a tumor of the middle lobe is sometimes accessible from the side.

Operations on tumors too large for removal, when the cranial opening was really made over the seat of the lesion, have not always proved so dangerous as in the class of cases just described. Thus, Horsley (Case 45) removed first one-half of the occipital bone, then the other, where an inoperable tumor of the middle lobe of the cerebellum existed. The patient had suffered for a long time from epileptiform fits, with violent rotary movements, from severe headache and distressing attacks of dyspnœa. All these symptoms disappeared after the operation, and the patient's life was prolonged in comfort for two years.

In Heath's case (27), also, there was found, over the right ascending frontal convolution, a large adherent growth which could not be removed. Localized tenderness had existed over the site of the tumor. The patient was relieved of his headache by the operation, and, at the time of reporting, had made a good recovery. In Case 35 (Limont and Page) a portion of a large glioma was removed, with temporary recovery, but the growth recurred.

In Case 39 (Kocher) tumor of the cerebellum was diagnosed from the four classical general symptoms, in the absence of focal symptoms. A double trephine opening was made to relieve intracranial pressure, one posteriorly on the right side below the tentorium, one anteriorly on the left side. In four days congestion of the optic discs had disappeared, but there was no improvement of vision.

In Maudsley's case (42) a tumor had been diagnosed in the left lobe of the cerebellum, the trephine was applied at this locality and a tumor found, but it was a solid nodule, irremovably attached to the temporal bone. The patient recovered from the operation. Five other cases proved rapidly fatal. The entire list of ten cases is summarized in Tables III. and IV.

Death occurred after removal of the tumor in sixteen other cases. The causes may be thus tabulated:

Five out of these 16 cases are tumors of the cerebellum; 5 cases on Table II., 1 on Table III., and 1 on Table V., were also cerebellar; thus 12 out of the total number of 46 unsuccessful cases, or 26 per cent.

The death from diphtheria (Castro) and that due to accidental opening of the cerebellar sinus (Bullard and Bradford) are theoretically avoidable. The case of gliosarcoma removed by McBurney had been correctly diagnosed eleven months before, and the operation then advised. At that time it might have been successful, so that in this case the fatal issue may fairly have been attributed to the delay. It may perhaps be assumed that the five deaths caused by septic meningo-encephalitis could have been avoided by more perfect antiseptic precautions.

The fatal issue is not clearly explained in the cases reported by Gray, Thomas, and Keen. The last case is particularly interesting, because the tumor had been correctly localized in the cuneus on account of the symptom of hemianopsia. It is the only case in the entire collection (before 1894) in which this symptom was thus rendered available.

In 39 cases the operation was successful. The situation of the tumor in these cases is shown in the next table.

These cases of recovery include one, and only one, case of tumor of the cerebellum, and that was a cyst. This is to be reckoned against 12 fatal cases of cerebellum tumor, already noted. As might be expected, in the immense majority of successful cases the tumor is situated in the motor convolutions (29 out of 39 cases). This region unites all the conditions of success—facility of diagnosis, facility of operation, relative freedom from danger of shock. Among the unsuccessful cases the tumor was situated in the central convolutions only seven times, and in one of these the death was purely accidental, due to an epidemic diphtheria. In all the others death was due to septic meningitis, in one case complicated by syphilis. In one a communication existed between the tumor and the ventricle; in another, there was an adhesion to the longitudinal sinus.

The symptoms of lesion of the central convolutions are so well marked that when the tumor exists in this locality it cannot easily be overlooked. It sometimes happens, however, that tumors in other localities simulate the symptoms proper to disease in the cortical motor centres. Thus: 1. The tumor may be situated in the subcortical region of the centrum ovale, as in Gray's case (84). The diagnosis in this case, notwithstanding the monoplegia, was correctly made as subcortical, on account of the absence of spasm or convulsion. 2. The tumor may lie in the frontal, parietal, or temporal lobes, and by transmitted pressure excite the symptoms proper to the motor area. The diagnosis, when possible, is made out by observing that lesions of intelligence, or speech, or sensibility, or vision, especially hemianopsia, have preceded motor symptoms, and that the latter remain incomplete—paresis, not paralysis. 3. Tumor of the basal ganglia may simulate cortical tumor. This occurred in Case 58 (Kerr). It is rather surprising that the mistake has not been made more frequently. That it has not, is due to the enormously valuable studies in "Jacksonian epilepsy," that may be ranked as the second link in the chain of investigation which, beginning with the researches of Hitzig and Ferrier on brain localization, have so rapidly led to brain surgery. Only one tumor of the occipital lobe has been operated on at its site, the diagnosis having been guided by the remarkable symptom hemianopsia (Birdsall and Weir, 15).

In Pilcher and Dana's case (31) the tumor occupied the left occipital lobe, but the operation was made at the site of a scar corresponding to the angular gyrus. The tumor, therefore, was not found. It is not stated whether the patient was examined for hemianopsia.

It is claimed, especially by Starr, that an onset of symptoms with psychical changes is very characteristic of tumors of the frontal lobe. Such mental depression, however, is apt to occur with intracranial tumors in any locality, and cannot be considered a distinct indication of frontal-lobe localization until, by extension backward, motor symptoms begin to complicate the mental; or until conjugate deviation of head and eyes has become a signal symptom in convulsive attacks; or until anosmia be discovered. In several of the frontal-lobe tumors here recorded an external lesion coexisted and guided the operator to the exact locality.

It seems to have become accepted that a fairly large opening through the skull is preferable to the small trephine openings originally chosen. With such large flaps much greater facility is offered for detecting a tumor, whose remote pressure symptoms had confused the preoperative diagnosis (see Gray's case).

From the foregoing record of cases we may deduce several propositions.

In the first place, it has been demonstrated that it is practicable to open the cavity of the cranium, to penetrate the dura mater, to lay bare the brain, and even to excise portions of its tissue. The successful removal of brain tumors has restored to favor as a legitimate surgical procedure the old operation of trephining, which had fallen into desuetude.* So far this surgical restoration has proved more useful in other cases of brain disease than in that which is the subject of the present article (see article on *Brain, Surgery of*). But the fact will always remain interesting, that it was the greater exploit of excising a cerebral neoplasm, which has, in entirely modern times, encouraged surgeons to the lesser effort of trephining for cerebral abscess and traumatic hemorrhage; and revived the old rules of unhesitating trephining in traumatic cases with depressed fracture.

Again, when Hughlings Jackson first began to study the precise order of development of the sensori-motor phenomena in the class of convulsive attacks which now bears his name, their habitual dependence upon organic brain lesion had not yet been established. This has now been shown, and the cases of brain tumor attended by attacks of Jacksonian epilepsy have assumed the most favorable prognosis, because the fact of the attacks usually indicates that the tumor is situated in the cortex of the central convolutions, and from the details of the attack the exact motor centre may be inferred. Pursuing still further the line of thought, neurological surgeons have argued that if a tumor in the motor area determines

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* Horsley, in a learned lecture, claims to have found evidence of operative trephining on the skulls of prehistoric men.

a definite series of explosive symptoms—sensori-motor irritation followed by sensori-motor paralysis—the occurrence of such symptoms, apart from indications of intracranial tumor, implies that the same motor region is irritated, though in some other way than by a neoplasm. Many cases of epilepsy, hitherto considered a functional disease,* have therefore been trephined, and in many of these, organic lessons, as cicatrices, have been removed from the surface of the brain or meninges, with the result of allaying or arresting the convulsive attacks. Finally, even in the absence of all visible lesion, portions of cortical tissue, containing the centres of motor representation corresponding to the limb segments whose spasm initiates the attack, have been excised.

It is not within the province of this article to discuss this latest and most interesting development of surgical method, which began with removing the tangible organic causes of epilepsy. We may observe, however, that the signal symptom of the attack (the felicitous expression is Seguin's), which is held to localize the lesion, because indicating the point of earliest and most intense irritation, does not necessarily show that the irritation originates at this point. It is quite as possible that the nerve tissue has received an irritation propagated from some distant region, but not manifest until it has spent itself upon a motor centre and thence determined a nervous discharge. Excision of the motor centre, therefore, would remove, not a cause of the spasm, but only the first effect of some possibly inaccessible cause.

From the frequent failure of the operation as a cure for epilepsy, one may suspect that some such condition of things often exists. The difficulty in these non-organic cases is paralleled in cases of tumor, when, though the convulsions are immediately initiated by irritation of the cortical motor area, the causal lesion is situated in some other part of the brain and cannot be found.

Another parallel has a more hopeful aspect. It has sometimes been found in cases of inoperable tumor that the symptoms due to pressure—vomiting, headache, and convulsions—could all be relieved when the pressure was lessened by trephining or removal of large pieces of cranial bones.† It seems therefore possible that in cases of epilepsy without gross or focal lesion, and before irremediable degeneration had set in, similarly afforded relief of intracranial pressure might arrest the disease.

Traumatism, even when not more severe than that of a fall on the head, has always been recognized as an important factor in the etiology of brain tumors. Out of the 85 cases of operation on record, there is a history of a fall or a blow in 20.‡ Morbid symptoms rarely develop very soon after the accident. months, sometimes years, intervene. In the light of the experience now accumulated, it is indicated to operate very early after the appearance of symptoms indicative of intracranial neoplasm; and the indication is especially formal if there is a history of previous traumatism. It is possible, as Seguin's case shows, to operate so early that the tumor has not yet grown large enough to be found at the operation. This is, however, the only case on the list in which the operation failed from this cause; only when the tumor is situated entirely on the surface of the cortex is it liable to excite convulsive twitchings while yet very small; but in such a situation the tumor should be easily found.§ The danger of delay in operating is well shown in the first case of Starr and McBurney (Case 81). Eleven months intervened between the establishment of the diagnosis (when the operation was first proposed) and the time when the patient's consent to the operation was secured. In that time the tumor grew to such a size that its removal was followed by death from shock in a few hours.

The development of optic neuritis is not always proportioned to the size of the tumor, but much more to its situation. Hence, as has long been known, optic neuritis appears early and advances rapidly with tumors of the cerebellum, where the intracranial pressure is at its maximum. An early operation is often indicated to relieve this pressure before the optic nerves should have atrophied, in which case the patient would remain blind, even though he survived the operation and were relieved of other urgent symptoms.

An important decision formulated by Horsley is that syphilitic tumors should be operated on, and not left to the uncertain influence of internal treatment. Bergmann, on the other hand, maintains the sufficiency of this treatment, and the superfluous risk of the operation.

If it be assumed that all tumors of the cortex and centrum ovale are conceivably operable, the proportion of operations to cases would be 41 per cent., since 266 out of 644 cases of tumor are situated in these two localities. If to these be added 162 cases of the cerebellum, the proportion would rise to 65 per cent.

The special difficulties surrounding tumor of the cerebellum have already been emphasized. The general diagnosis is relatively easy, that is, it is usually easy to diagnose a tumor of the posterior cranial fossa and subtentorial. It is often difficult to distinguish between the middle lobe of the cerebellum and a lateral lobe; and usually impossible to distinguish between tumor of the bone compressing the cerebellum and tumor of the organ itself. A precious aid in diagnosticating tumors of the occipital lobe from those of the cerebellum is the existence of hemianopsia in the former, as against optic neuritis in the latter. Case 41 (Keetley) shows how a tumor of the pons may be mistaken for a cerebellar tumor, when by exception the paralyses of cranial nerves, so characteristic of pontine tumors, are lacking. The prognosis in cerebellar tumors, however, is rendered bad far less by the difficulties of diagnosis than by the special dangers of the operation which have already been mentioned. In the centrum ovale and cortex, on the contrary, the dangers of the operation are at the minimum, provided the tumor can be found. The difficulty of finding it depends upon: 1st, whether it lie in a latent zone or in one whose symptomatology has been determined; 2d, upon its proximity to the surface; 3d, upon the differentiation of its consistency from that of the brain.

The accessible regions of the cerebrum whose lesions have so far been connected with sufficiently definite differential symptoms are: The frontal lobes, the central convolutions, the parietal lobes, the occipital lobes, the left temporal lobe, and the left insula. The differentiating signs have been sufficiently emphasized in the text. Tumors of the centrum ovale are always latent as to their locality—being indicated by general symptoms alone, unless they come near enough to the surface to irritate the cortex. In Gray's case (86), Table I., the position was made out with great precision, but the failure was due to the third operative difficulty which has been mentioned, namely, the extremely soft consistency of the tumor.

This difficulty can never be foreseen in advance, and seems to be as much to be feared with large as with small tumors.* Possibly some future therapeutic resource will enable the surgeon to prepare his patient for operation by the ingestion of some food or drug which should change the consistency of the tumor.

Medical resources at present are extremely meagre—after we have mentioned the use of mercury and iodide of potassium in cases of syphilitic tumor. An energetic inunction treatment is required, 4 to 5 gm. mercurial ointment daily for six weeks—followed, after a pause, by a course of iodide of potassium, 5 to 10 gm. to 200 gm. of water, of which a tablespoonful three times a day.

For vomiting, pain, and convulsions, morphine, chloral, and bromide of potassium are the three remedies, and the greatest of these is morphine. For details of cranio topography, operative procedure and technique, and the special dangers incident to the operation for brain tumor, the reader is referred to the article on *Brain, Surgery of,* by Dr. Keen, in the present volume.

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* According to the present view, non-localizable, *i.e.*, generalized epilepsy depends upon a diffused microscopic sclerosis (Féré, "Les epilepsies") or a degeneration and vacuolation of ganglion cells (Dana, "Treatise on Nervous Diseases").

† Horsley (see Case 45) removed first one half, then the other half of the occipital bone, "and the patient lived in comfort two years."

‡ Cases 1, 3, 5, 16, 18, 24, 31, 37, 38, 41, 49, 55, 58, 68, 74, 75, 76, 80, 82. Case 38 is particularly interesting. It is that of a little girl in a Swiss school who was struck on the head with a ruler by the teacher.

§ In Case 50 (Church) the tumor was a spider-like, filiform growth, extended on the surface of the central and frontal gyri.

* It is characteristic of gliomata.

Mary Putnam-Jacobi.

BRANCHIAL CYSTS.—Branchial cysts are cystic tumors of the neck and some parts of the head, originating from congenital defects of development, their matrix being composed of fœtal epiblastic or hypoblastic tissue which remains in its embryonal state for an indefinite time, and later, by proliferation of its epithelial elements, gives rise to a distinct and characteristic type of cystic tumors. They have been variously designated as branchial cysts (Roser), dermoid cysts of the sheath of the internal jugular vein (Langenbeck), deep-seated atheromatous tumors (Schede), tumors of the branchial clefts (Virchow), hydrocele colli congenita (Maunoir), hygroma colli (Luschka), and atheromatous cysts of the lymphatic glands (Luecke), in accordance with the nature of the contents of the tumor or the peculiar etiological views entertained by the different authors. It appears to me, however, that "branchial cysts" is the most appropriate term, as it expresses at once both the location and the character of the tumor.

Toward the end of the first month of fœtal life we see, under the frontal process, open in front and bounded on the sides by four plates, the pharyngeal cavity. The upper pair of plates constitutes the first branchial arch. The next three pairs of plates make up the second, third, and fourth branchial arches, which decrease in size from above downward, so that their median interspaces in front are narrow above and wider lower down. Between any two individual branchial arches, on each side, remains a transverse cleft, and, during early fœtal life, these branchial clefts, with the exception of the first one, from which the external auditory canal, the cavity of the tympanum, and the Eustachian tube are developed, unite. The neck is thus built up of continuous lateral walls. From the second branchial arch are developed the styloid process, the stylo-hyoid ligament, and the lesser cornua of the hyoid bone; the third arch forms the large horns and the body of this bone; the fourth arch assists in forming the soft tissues of the neck. The larynx, trachea, and adjacent glands are developed from other centres of fœtal growth. The primary origin of these tumors necessarily must correspond to the location of one of these branchial clefts, and clinical experience has demonstrated that they are most frequently found in the region of the second and third branchial clefts, in the vicinity of the larynx and pharynx, and in intimate relation with the sheath of the large vessels of the neck, in contradistinction to dermoid cysts about the orbits and in the scalp, which are more superficially located. In the case of a young lady, Langenbeck observed a cyst situated on the left side of the epiglottis and pharynx, which occupied one-half of the floor of the mouth, and which projected from underneath the chin on that side in the shape of a smooth tumor of the size of a fist. Respiration, deglutition, and the motions of the tongue were greatly impeded. The cyst contained eight ounces of atheromatous matter. The same author states that he has frequently found these tumors attached to the greater horn of the hyoid bone or to the thyro-hyoid ligaments, localities which plainly indicate that they originated from remnants of former branchial clefts.

As they are often in intimate connection with the sheath of the large vessels of the neck, it is very important to study their anatomical relations to these important structures. The jugular vein is surrounded, throughout its whole course in the neck, by a distinct and separate sheath of areolar tissue which, on the outer side of the artery, penetrates into the deep tissues of the neck, thus completely separating the two vessels. The jugular, enclosed in its sheath, may be easily drawn over the artery toward the median line without producing any change of location of the artery. The vein being in front of the artery and covering half of the lumen of the latter, it can be readily understood that when the vein is drawn forward, with its sheath, it can be injured, while the artery is not exposed to the same danger. Branchial cysts of the second and third clefts are always observed in the sheath of the large cervical vessels, usually in the carotid triangle above the omo-hyoid muscle. They appear to occur more frequently on the left side of the neck. Their shape is invariably round or oval, with a smooth surface. The contents of these cysts being either fluid or semifluid, fluctuation can be felt, more particularly if the tumor is palpated between two fingers, one of which is placed in the pharynx or on the floor of the mouth, and the other on the external surface. Only lateral motion of the tumor is possible, on account of its peculiar attachments to the deep tissues of the neck. If the tumor is of only moderate size the pulsations of the carotid artery can be felt on its inner margin. If it is large it overlaps the artery, in which case the pulsations of the vessel are communicated to the tumor. Smaller tumors can be made to pulsate by bending the head backward and in a direction opposite to the tumor.

Branchial cysts should be classified according to their contents. The cyst walls being lined with epithelium, the only histological elements in the contents are epithelia. In most instances the epithelia lining the cyst belong to the tessellated variety, but Rehn discovered, in a blind congenital fistula ending near the mucous membrane of the pharynx, ciliated epithelium; and Neumann found cylindrical and pavement epithelium in two cystic tumors of the neck, one of which was congenital while the other was developed in later years. The physical and chemical properties of the cyst contents will depend largely on the amount and degree of activity of the retrograde processes which may have taken place in the epithelium.

Clinical experience and pathological examination have shown that these tumors, according to the physical properties of their contents, may be divided into the following four principal varieties:

1, Mucous cysts; 2, atheromatous cysts; 3, serous cysts; 4, hæmato-cysts.

Variable as the contents of these varieties may be, more uniformity is observed in the structure of the cyst wall. In the primary stage of the affection it consists of a connective-tissue capsule with an epithelial lining on its inner surface, and a delicate layer of a loosely connected reticulum of connective tissue (pericystium) which is very vascular, and covers the outer surface of the cyst. A high degree of intracystic pressure may cause atrophy of the epithelial lining and thinning of the walls of the sac, and, on the other hand, inflammatory proliferation produces great thickening of the cyst walls. While dermoid cysts contain the characteristic secretions of the skin and its appendages, the branchial cysts contain only the products of the epithelial cells, because their walls do not contain any hair follicles, sebaceous or sweat glands, as the branchial clefts close before these appendages are formed.

1. Mucous Branchial Cysts.—As a primary formation, this form of branchial cyst is usually found in the upper branchial clefts. Their origin is attributable to an imperfect closure of the upper portion of the branchial tract; consequently the cyst wall may derive its lining from the mucous membrane of the pharynx, and the retention of the physiological secretion produces a mucous cyst. Many of the so-called ranular cysts, about the base of the tongue, belong to this variety of tumors.

2. Atheromatous Branchial Cysts.—This form of branchial cysts has been described by some authors as deep-seated atheromatous cysts of the neck (Schede), and dermoid cysts of the sheath of the large vessels of the neck (Langenbeck). They are usually located in the second and third branchial tracts in the region of the hyoid bone, and are intimately connected with the sheath of the large cervical vessels. These cysts contain an atheromatous material resembling the contents of an ordinary retention cyst of the skin, with this difference, however, that they never contain anything which would

indicate the presence of hair follicles, as lanuginose hair or sebaceous material, or any of the more complicated products of a dermoid cyst. For the purpose of furnishing a clear clinical picture of this form of branchial cysts, I will give a synopsis of two cases which have come under my observation.

Case I.—Mrs. H——, aged thirty six. German. Family history reveals no tendency to congenital malformations. About one year ago the patient discovered a small tumor on the right side of the neck, between the angle of the jaw and the larynx, which slowly increased in size, and after a few months became the seat of an acute inflammation which terminated in suppuration, requiring an incision for the relief of urgent symptoms. The fluid which escaped consisted of pus mixed with a gruelly substance. Prompt relief followed the incision. The inflammatory symptoms subsided and the tumor diminished in size. In a few weeks the opening closed, leaving a small and painless swelling. The same symptoms were repeated about four months subsequently. When the patient came under my observation, during the summer of 1883, I found a tumor about the size of a hen's egg, located between the angle of the jaw and the larynx, resting directly upon the large vessels of the neck, as was evident from the distinct pulsations which it received and which could be seen and felt. The posterior portion was under the sterno-cleido-mastoid. Over its centre was seen the scar which had resulted from the previous incisions. The swelling presented a regular, smooth surface and an oval outline, with the long diameter parallel to the cervical vessels. It was only slightly movable from side to side, and perfectly immovable from above downward, showing that it had a firm point of attachment to the deep tissues of the neck. Fluctuation could be detected on the outer surface and also through the mouth. The original location corresponded to the third branchial cleft. As it had on two different occasions undergone acute inflammatory changes without any benefit resulting from them, the extirpation of the cyst was deemed the only measure which promised a permanent result. The operation was done under antiseptic precautions. A straight incision was made over the tumor, parallel to the sterno-cleido-mastoid. The cyst was firmly adherent to the surrounding tissue, as the result of antecedent inflammatory infiltrations, and required much time and patience to effect its separation. After it had been isolated from all attachments on its sides, it was seized with a tenaculum forceps and drawn forward and toward the median line of the neck, while the sterno-cleido-mastoid was held in an opposite direction, so as to afford easy access to its base. The attachments here were very firm, and it appeared as though the base of the tumor and the large cervical vessels underneath were embedded in a mass of cicatricial tissue. Keeping as close to the cyst wall as possible, I carried out the dissection very carefully, proceeding mostly with blunt instruments. When nearly one-half of the pedicle had been separated in this manner, we were suddenly surprised by a tremendous gush of dark venous blood, which in a second flooded the whole field of operation. It was only too evident that the internal jugular vein had been torn, and, for the purpose of preventing further loss of blood, and to guard against instant death by admission of air into the vein, I made firm digital compression above and below the injured vein, while my assistant pushed a sponge into the wound. Hemorrhage was controlled in this manner, and, as soon as I could be relieved by an assistant, I carefully removed the sponge, and, after locating as nearly as possible the exact seat of bleeding, I seized the vein, with some of its adjacent tissues, with a stout pair of hæmostatic forceps. I was fortunate enough to grasp the bleeding point at the first attempt, and the hemorrhage was completely controlled. The tumor was now removed, and by making slight traction on the forceps I drew the vein forward and applied a catgut ligature without isolating the vessel. I was unable to ascertain the exact size or direction of the wound in the vein, but the ligature arrested the hemorrhage promptly and permanently. The wound was thoroughly irrigated, and, as in Langenbeck's case, the vein seemed to disappear underneath the deep tissues of the neck. In the wound could be seen the œsophagus, lateral wall of the larynx, carotid artery in its sheath, and the great horn of the hyoid bone. After suturing and draining the wound I applied a graduated compress. For the first twenty-four hours after the operation the patient suffered from intense headache on the corresponding side, which induced me to believe that the circulation in the vein had been completely interrupted, either by the ligature alone or by the formation of a thrombus at the point of ligation. After the first twenty-four hours the patient suffered no further inconvenience. The wound healed by primary union, and the recovery has been permanent and complete. There is no question that the adhesions of the cyst with the sheath of the cervical vessels were due to the attacks of acute inflammation which had preceded the operation on two different occasions. A microscopical examination of the contents showed flat epithelial cells, cholesterin crystals, fat granules, and a mass of débris, the product of epithelial degeneration. The cyst wall was composed of connective tissue, thickened and infiltrated with embryonal elements, and lined with epithelial cells.

The next case very nicely illustrates the oral variety of branchial cysts.

Case II.—Mary H——, aged twenty-five. German. Her family history is good, especially as regards congenital malformations, such as tumors or fistulæ in the cervical region. Patient has always appeared round and full underneath the chin, but during the last four years a tumor has been growing rapidly on the floor of the mouth, until at present it is considerably larger than a goose's egg. The mouth is completely filled by it, the tongue is pressed against the palate, its movements are limited, only the tip of it being visible at the upper border of the tumor, and speech and deglutition are greatly impeded. Laterally the tumor extends very near the angles of the inferior maxillary bone, and downward it overlaps the larynx and upper part of the trachea, entirely obliterating the round contour of the upper cervical region. It is painless and distinctly fluctuating to the touch, presents a smooth surface, and gives rise to no inconvenience except that which results from its mechanical interference with speech and deglutition. When the patient opens her mouth, the apertures of Wharton's ducts are plainly visible on each side of the median line, and, by exerting lateral pressure upon the submaxillary glands, the patient can expel a stream of saliva from them. Previous treatment, consisting of external applications of iodine, etc., had had no effect on the growth. Desiring to avoid any deformity resulting from an external cicatrix, I decided to remove the tumor through the mouth. A linear incision was therefore made in the median line, extending from above downward from the tip of the tongue to the symphysis menti, the ducts of the salivary glands being carefully avoided. Adhesions existing between the tumor and its surrounding tissues were easily severed, when it was seen that it would be impossible to remove the tumor in its entirety owing to its immense size. The sac was therefore opened and a large quantity of its gruelly contents removed by pressure. The operation was then continued without any difficulty until the entire cyst had been removed. It was now noticed that the cyst was constricted in its middle by the inferior maxillary bone, the upper and lower portions of it bulging out on both sides of the constriction. There was no hemorrhage worth mentioning. The body and great wings of the hyoid bone could be plainly felt in the posterior recess of the wound. The cyst wall was thin, and its external surface was quite vascular. The microscopical examination of the contents of the cyst, as well as the primary location of the tumor, revealed its branchial origin. The wound healed very kindly, and shortly afterward nothing in the looks of the young lady showed any traces of the deformity which had previously disfigured her face and neck.

3. Serous Branchial Cysts.—This variety of branchial cysts is composed of thin cyst walls and serous contents, and may develop from any one of the branchial clefts failing to undergo complete obliteration. This affection has been described under the name of *hydrocele colli* (Maunoir), congenital hygroma of the neck (Wernher), congenital hydrocele of the neck, and congenital cystic tumor of the neck (Thomas Smith). Maunoir, under the name of *hydrocele colli*, described certain serous cysts occurring between the angle of the jaw and the mastoid process, and between the larynx and the anterior margin of the sterno-cleido-mastoid, a region which corresponds to the second and third branchial clefts, which were supposed not to have been obliterated at the time of birth. We have seen, however, that branchial cysts are not necessarily developed during intra-uterine life or soon after birth. All that is necessary is that the matrix for the cysts be present at birth, from which at some future time the tumor may be developed. These tumors appear as single or multilocular cysts with thin membranous walls; their internal surface is lined with pavement epithelium. Like cavities lined with a serous membrane, they contain a limpid, watery, or tenacious fluid, holding in suspension epithelial cells and cholesterin crystals. These cysts are formed anywhere in the neck, within the area of the branchial clefts, between the lower jaw and the clavicle. They are usually deep-seated, though occasionally they are superficial. They are painless, and give annoyance only from their size. Clinically they may be recognized from their location, their globular cystic form, soft fluctuating feel, and painless growth. The existence of tessellated epithelium upon the inner surface of these cysts has been demonstrated by Neumann and Baumgarten. When these cysts spring from the second or third branchial clefts they are usually deeply located. Hueter, in extirpating a tumor of this kind in a child two years of age, ascertained that it extended between the two carotid arteries back to the walls of the pharynx. When they are deeply situated they are usually in contact and connected with the sheath of the large cervical vessels, and receive a distinct impulse from the underlying artery. When thus located, they offer the same difficulties to extirpation as do those of the atheromatous variety. The following case may serve as an illustration of this type of branchial cysts:

The patient was a healthy, strong, male child, six months of age. No history of congenital malformation, especially branchial fistula, in the family. When the child was born, a small tumor the size of a pea was discovered on a level with, and somewhat to the inner side of, the sternal origin of the sterno-cleido-mastoid muscle. The tumor was painless and movable, but rapidly increased in size. When the child was brought to me, the tumor was as large as a walnut. The skin over it was natural in appearance and movable. The tumor itself presented a smooth surface. Fluctuation was distinct, but the cyst appeared to be somewhat firmly attached to the adjacent tissues. The cyst was readily enucleated, the adhesions not being very firm except over the most prominent point of the tumor, where inversion of the skin had undoubtedly occurred during the closure of the external opening of the fourth branchial tract. The adherent portion of the skin was excised with the tumor. The cyst was found to be oval in shape and smooth, and the outer layers were quite vascular. The walls being thin and the contents serous, the whole tumor presented a translucent appearance. The wound was closed with sutures, and healed by primary union under an antiseptic dressing. Similar cases have been reported by Smith, Vonwiller, Frederick Treves, and others.

Thomas Smith reports a case which would show that these cysts may occasionally disappear by spontaneous absorption of their contents. The patient was a healthy babe three weeks old. Immediately after birth a swelling was noticed in the neck, which rapidly increased in size. When the patient was first seen, a cystic tumor occupied almost the entire region of the left side of the neck, extending from under the lower jaw to the clavicle. The mother objected to any kind of treatment. Three months later the child was seen again, when the growth had greatly diminished in size. There was nothing to be felt but a loose, flabby, cystic mass, not much larger than a hen's egg. The skin over it was shrivelled, loose, and baggy. Three months later the tumor was still smaller.

4. Hæmato-cysts of Branchial Clefts.—In some instances of serous branchial cysts the fluid is discolored by an admixture of blood from minute hemorrhages into the sac, but when the contents are of such dark color as to resemble venous blood, they are properly called hæmato-cysts, and from a pathological, diagnostic, and clinical point of view they constitute a distinct and well-marked variety of branchial cysts. Albert remarks that two kinds of these cysts have been observed: 1. Such as may be emptied by pressure, and are in communication with blood-vessels. 2. Those which cannot thus be emptied by pressure, and which simulate the appearance of an ordinary serous cyst so closely that their nature is recognized only by puncture. The latter class, when they occur in the neck, usually belong to the branchial cysts, because they are observed during early life, and originate in places which correspond to the location of the branchial clefts. This variety of cysts has been called *hæmatocele colli* by Michaux and *hæmatoma* by J. P. Frank. Hæmato-cysts resemble the serous cysts in every particular, with the exception of the presence of blood in their contents. It is not an easy matter, however, to make a diagnosis of this variety of branchial cysts, and it should always be made by exclusion, due attention being given to the location of the cyst, the time of development, and the character of its contents.

Branchial cysts are of comparatively rare occurrence, and the statistics cannot be relied upon in estimating the frequency with which these tumors occur, as many of them have been classified and described under the generic and indefinite term "cystic tumors of the neck" without regard to their etiology. Guret, in 1855, compiled 44 cases of serous and 6 cases of atheromatous cysts. Since that time quite a number of new cases have been described by Volkmann, Billroth, Esmarch, Roser, Langenbeck, Luecke, and Bruns. The serous variety of cysts is more likely to develop early; they are often congenital, or appear during infancy or childhood, while the atheromatous cysts are the products of early adult life. Of 53 cases mentioned by Schede, 9 occurred between the first and tenth years of life, 21 between the eleventh and twentieth, 10 between the twenty-first and thirtieth, 6 between the thirty-first and fortieth, 5 between the forty-first and fiftieth, and 2 between the fifty-first and sixtieth.

Like the dermoid cysts, the branchial tumors show a tendency to develop during the period of puberty, at a time when the epiblast enters upon a new phase of development and becomes the seat of renewed and active tissue proliferation. The remnants of the branchial cleft may remain dormant, as a matrix for the future growth of the tumor, for an indefinite time, and may become the seat of tissue growth during puberty or upon the advent of any determining cause or causes. There are many instances in which remnants of fœtal tissue have remained latent in the branchial tracts throughout a lifetime, for want of an exciting cause of sufficient strength to call into morbid activity the slumbering forces inherent in the histological elements of the matrix.

Diagnosis.—The diagnosis is oftentimes no easy task. The importance of the tissues and organs which are in close and intimate relation with these tumors renders it imperative upon the surgeon to make a correct diagnosis before an operation is undertaken for their removal. The following conditions may simulate a branchial cyst: 1, Aneurism; 2, angioma; 3, dermoid cysts; 4, retention cysts; 5, affections of lymphatic vessels and glands; 6, struma cystica; 7, simple serous cysts.

1. *Aneurism.*—As most of the branchial cysts are in immediate contact with the large cervical vessels, and

usually receive the impulse from the underlying artery, it is always important to exclude the possible presence of an aneurism. At the age when branchial cysts are most frequent, aneurisms, except of traumatic origin, are exceedingly rare. Pressure does not affect the volume of a branchial cyst, and the pulsations are felt only in one direction, away from the artery. Auscultation furnishes another important negative symptom. An exploratory puncture, which should always be made in doubtful cases, will also furnish valuable information, as it will afford an opportunity to examine the contents of the tumor. In hæmato-cysts the contents may resemble venous blood, but a microscopical examination will show, in addition, the presence of epithelium or the products of epithelial degeneration.

2. *Angioma.*—Deep-seated angiomata are occasionally met with in children, and, as the skin may present a perfectly natural appearance, they might be mistaken for branchial cysts. If the tumor disappears under pressure it may be an angioma, but never a branchial cyst.

3. *Dermoid Cyst.*—As dermoid cysts may occur in the same localities and at the same age, they are frequently mistaken for branchial cysts, and *vice versa.* As both varieties of cysts require the same treatment, a positive diagnosis is not essential. A correct anatomical diagnosis can be made by examining the contents and the cyst walls. A branchial cyst contains only one constant histological element—epithelium,—as obliteration of the branchial tracts takes place long before the appendages of the skin are formed. A dermoid cyst, on the other hand, contains the products of secretion of the skin and its appendages. The walls of a branchial cyst are composed of a connective-tissue capsule lined with epithelium, while the sac of a dermoid cyst is composed of true skin.

4. *Retention Cysts.*—The only two forms of retention cysts which call for consideration in this connection are the true atheroma of the skin, the result of obstruction in the ducts of the sebaceous glands, and the retrotracheal cyst, which originates in a similar manner in the retrotracheal glands. Cysts arising from the second and third branchial clefts are always deeply located, and when first observed are distant from the skin, while an atheroma primarily develops in the skin, and usually grows in a peripheral direction. Lanuginose hair is sometimes found in the contents of an atheroma, the product of retained hair follicles; it is never seen in branchial cysts.

Virchow has called attention to a peculiar kind of retention cyst which is found between the œsophagus and the trachea, and which arises from an obstruction in the duct of one of the retrotracheal glands. These glands are situated between the trachea and œsophagus, but their ducts traverse the entire thickness of the tracheal wall and terminate upon the free surface of the mucous membrane. These cysts are so located that they give rise to distressing symptoms, referable to deglutition and respiration, before they attain any considerable size, differing greatly in this respect from the clinical history of a branchial cyst.

5. *Affections of Lymphatic Glands and Vessels.*—A deep-seated, isolated, caseous, lymphatic gland might be easily mistaken for a branchial cyst, more particularly after the cyst had become the seat of inflammatory infiltration. It is seldom that we meet any such extensive pathological changes in a single lymphatic gland as to simulate a branchial cyst, without participation of one or more adjacent glands. Again, in cases of diseases of the lymphatics, the general condition of the patient usually indicates the existence of a serious affection, while a branchial cyst is a purely local condition, never affecting the general health except when it interferes with important functions of the neighboring organs. Cancerous or sarcomatous affections of the lymphatic glands would reveal themselves by the clinical symptoms characteristic of these tumors.

6. *Struma Cystica.*—Cystic degeneration of the thyroid gland proper can never be mistaken for a branchial cyst, as the connection of such cysts with the thyroid body can be traced without any difficulty; but recently it has been ascertained that not infrequently small accessory thyroid glands exist in the neck which may undergo cystic degeneration, and Madelung has made the assertion that the so-called hydrocele of the neck is only a struma cystica of a supernumerary thyroid gland. The possibility of a cystic degeneration of such an accessory thyroid body should always be borne in mind in examinations for branchial cysts.

7. *Simple Serous Cysts.*—Virchow asserts that many of the serous cysts develop without a particular matrix, as new formations, in the connective tissue. It is a well-known physiological fact that the connective-tissue cells are occasionally converted into endothelia, as during the formation of new synovial membranes; hence we should *a priori* expect that in simple serous cysts, developed from connective tissue, the inner surface of the sac would be lined with endothelia the existence of which would be sufficient to disprove their branchial origin.

In repetition I will enumerate the following points, which should be considered in the differential diagnosis of cystic tumors of the neck with special reference to branchial cysts: 1. Primary seat of tumor; 2, effect of pressure; 3, general condition and age of patient; 4, character of contents.

Prognosis.—Branchial cysts always remain purely local affections and manifest no tendency to destroy life, except when they are of sufficient size to interfere, by their pressure, with the performance of important functions of neighboring organs. On the other hand, it may be said that they manifest no tendency to spontaneous cure, and prove exceedingly obstinate to all forms of treatment short of complete extirpation.

Treatment.—The inner surface of branchial cysts being lined with epithelium, it is evident that obliteration of the sac can be obtained only after the destruction or removal of this epidermal lining. The radical treatment for the removal of these tumors must have for its object either the production of an artificial inflammation, in the interior of the sac, of sufficient intensity to destroy the epidermal matrix, or complete extirpation of the cyst. The former procedure is exceedingly unreliable, and extirpation in many instances must be looked upon as a very formidable and dangerous operation. The following means have been employed in the treatment of branchial cysts: 1, incision; 2, actual cautery; 3, seton; 4, puncture, with subsequent injection; 5, extirpation; 6, antiseptic drainage.

1. *Incision.*—In all cases in which incision was practised, the relief from existing symptoms was prompt; the cyst collapsed, a certain amount of inflammation was established, suppuration followed, and in some instances the patient and surgeon were led to believe that a radical cure was obtained. Usually, after healing of the wound, a small nodule remained, which in a few months again became the seat of active tissue growth, and a speedy relapse was an almost constant occurrence. In infants the laying open of cysts is a perilous plan of treatment. Volkers relates a case in which a cystic tumor was laid open in a new-born child, who died sixteen days afterward in consequence of the operation. A branchial cyst cured by simple incision is reported by Billroth. In the case of serous cysts, in which the seton and iodine injections have occasionally been successful in producing obliteration, it seems to me that the same object would be accomplished more speedily and safely by incision and drainage practised in a similar manner as in Volkmann's operation for hydrocele.

2. *Actual Cautery.*—Dieffenbach employed the actual cautery in opening the cyst in one of his cases, after he had made an unsuccessful attempt at removing it by extirpation, and after incision had failed in producing obliteration of the sac. The use of the cautery met with no more encouraging result. It would seem to me that incision, combined with an energetic use of the cautery, would be most applicable in the most dangerous and formidable class of cases, viz., cysts which have become

firmly adherent to the sheath of the cervical vessels by repeated attacks of inflammation.

3. *Seton.*—This form of treatment proved successful in several of Thomas Smith's cases of serous cysts of the neck, but in some of them their branchial origin does not appear to be established. Smith uses a single thread of silk, and removes it before suppuration sets in. If the tumor is polycystic, he attacks only one cyst at a time. Gurlt very justly has entered his protest against the use of the seton. As in the case of hydrocele, the seton is an exceedingly uncertain agent in calculating with precision the amount of inflammatory action which will follow its use. The degree of irritation produced by it is very liable to be inadequate to produce adhesion, or it exceeds the desirable boundary, and induces suppuration with all its evil consequences. Butlin reports the case of a young child in whom a seton was passed through a serous tumor, and which was followed by death on the third day from the violence of the inflammation. For this and other obvious reasons the seton should never be used in the treatment of branchial cysts.

4. *Puncture, with Subsequent Injection.*—In the transactions of the Fourth Congress of German Surgeons, the treatment of branchial cysts by puncture and injection was fully discussed. Esmarch's experience appeared to be the most extensive, and his results were more uniformly favorable than the practice of any other surgeon. He claims to have cured about a dozen cases by puncture and subsequent injection of Lugol's solution of iodine (Iodi, pot. iod., āā 1.25; aquæ, 30.0). Whenever complete obliteration does not follow the first puncture, he repeats the operation. This method of procedure is as follows: By means of a fine hydrocele trocar the sac is emptied of its contents, when repeated injections of a one-per-cent. solution of carbolic acid are made to remove the masses of epithelium adherent to the cyst wall. These injections are continued until the water returns perfectly clear, then Esmarch injects from 10 to 20 gm. of Lugol's solution of iodine, which, after gentle pressure, to bring it in contact with the inner surface of the sac, is allowed to escape. The patient is then directed to return in six or eight weeks. Like a hydrocele, the cyst refills rapidly and becomes somewhat painful. If after the lapse of the time mentioned the tumor has not greatly decreased in size, the same operation is repeated, and in about six months the cyst will be found atrophied to a small tubercle. According to Esmarch, the cure in most cases has been permanent. From the discussion which followed Esmarch's remarks, it is evident that the majority of German surgeons have no confidence in the efficacy of iodine injections in obliterating branchial cysts. If we consider the numerous failures of iodine injections in cases of hydrocele, in which the anatomical conditions for success are so much more favorable, we shall be better prepared to appreciate the causes of its still more frequent failures when used in the treatment of branchial cysts. In infants, even simple tapping is not always devoid of danger, as one instance of death is recorded caused by puncture. The case occurred in the practice of Volkers, who tapped a cystic cervical tumor in an infant eight days old, the child dying of trismus on the third day.

5. *Extirpation.*—A positive diagnosis made, the best plan to pursue is to make an incision over the most prominent portion of the tumor, and, in case the adhesions can be separated without endangering the deep cervical vessels, the entire cyst should be removed. If inflammatory infiltrations obscure the field of operation at the base of the tumor, and after careful examination it is not deemed advisable to perform complete extirpation, the sac should be opened and the lateral walls excised; then the epidermal matrix which remains adherent to the sheath of the cervical vessels can be destroyed completely by a careful but vigorous use of the actual cautery. If an early diagnosis is made, and prompt treatment instituted, complete extirpation should always be attempted, and will, in the majority of cases, prove successful and comparatively free from danger.

6. *Antiseptic Drainage.*—In the case of infants and very young children suffering from large serous cysts, it would be imprudent to resort to any of the severer measures with a view to a radical cure. In such instances, drainage under antiseptic precautions should be resorted to as a temporary measure, and in some instances it may be followed by permanent results. The same course of treatment should be adopted in adults suffering from cysts which are inaccessible to any other operation, and in which irritating injections are contraindicated.

Nicholas Senn.

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BREAST, FEMALE.—The breast (L. *pectus*, Ger. *Brust*, It. *petto*, Fr. *sein*) is one of the two rounded eminences situated, in the human species, one on either side of the thorax, and in the female secreting the milk for the nourishment of the new-born. They constitute the mammary glands and associate structures, that is, the true gland tissue, the stroma, and integument including nipple and areola.

The presence of mammary glands (L. *mammæ*, Fr. *mamelles*, Ger. *Brustdrüsen*, It. *mamette*), zoologically considered, constitutes one of the most important considerations for grouping into one class (mammalia) all those animals possessing them. They are found in both male and female, but the size and development differ; the male gland as a rule remains throughout life in the embryonic condition, while the female breast passes through marked and important changes at puberty, at conception, after lactation, and at the menopause.

Embryology.—In very early embryos, there is observed on either side a slight streak, running from the root of the stump-like fore-limb to the hind-limb, and situated a little behind and parallel to the membrana reuniens inferior. This is observed in rats of 2.5 to 5.25 mm. (Henneberg) and in human embryos of from 4 to 8 mm. (Hirschland and Strahl), and was named by Schwalbe-Schmidt mammary streak (Milchstreifen). It is due to the cells of the ectoderm becoming deeper and more cubical.

From the mammary streak there is soon produced, by multiplication of the cells, a well-marked ridge, the mammary line (Milchlinie or Leiste) (*Ml*, Fig. 1035, A). This well-marked microscopic ridge was first studied by O. Schultze in the pig, and more recently by Kallius, Stahl, and Hirschland in human embryos of about 15 mm.

In this line the epithelium develops more rapidly at certain spots, corresponding in situation and number to the future mammary glands. The line becomes moniliform, and finally isolated, spindle-shaped enlargements are produced by atrophy of the portion of the milk line lying between the enlargements (Fig. 1035, B). Thus the mammary hillocks ("Milchhügel") of Bonnet are produced (Fig. 1036). The projection of the line of hillocks, above the surface of the skin, is only very transient. In human embryos, toward the end of the second month of intra-uterine life, the small tubercular thickenings, gradually increasing in size, become lens-shaped, and their convex surfaces project into the cutis, forming the mammary points (Milchpunkte). Large numbers of the mesodermic cells of the cutis collecting around the epithelial ingrowth form a condensed zone (nipple zone; *cf.* Fig. 1036), from which later the nipple is developed.

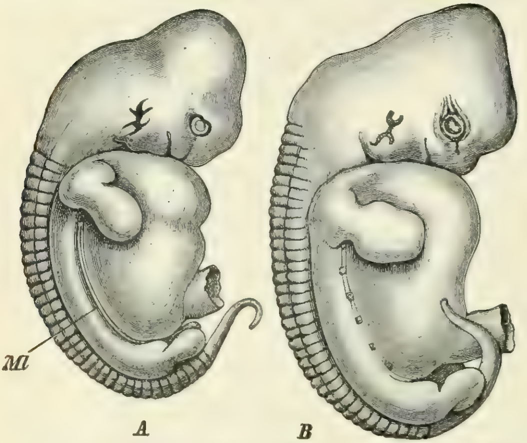

FIG. 1035.—A, Pig Embryo 1.5 cm. long. *Ml*, Mammary line. B, Pig embryo 1.9 cm. long, with mammary hillocks. (O. Schultze.)

The further growth results in flattening above with a projection of the deeper convexity of the lens, especially in the centre. In this way there is produced a cone-shaped mass of the cells which sink deeper into the cutis.

Around the apex of the cone the greatest activity is manifest; the cells push deeper into the cutis, and spread out below to produce a large ball-like mass (body) connected with the surface by a narrow elongated part (neck; Fig. 1037). This is the so-called club-shaped stage.

There now appears on the free surface of the skin a small cavity, the "gland area" (Drüsenfeld of Huss), which soon deepens. In the formation of this not only the deep but also the superficial layer of the epithelium takes part. Around the border of the depression a ring-like ridge of cutis, the first rudiment of the areola, is raised up.

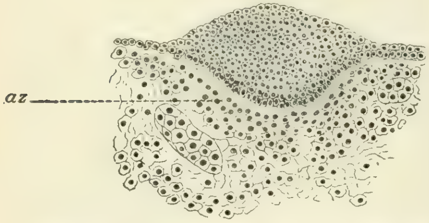

FIG. 1036.—Mammary Hillock of a Pig Embryo 1.5 cm. long, with the Nipple Zone (*az*) becoming Differentiated.

Upon the deep surface of the club-shaped mass, at about the twelfth week of intra-uterine life, small bud-like masses of the epithelial cells appear (Fig. 1038). These rapidly increase in length, and force their way as solid plugs into the mesoderm beneath (Fig. 1039). This secondary epithelial development is the rudiment of the true secreting portion of the gland. The number of epithelial sprouts now seen (fifteen to twenty) corresponds with the number of excretory ducts which the mature glands will possess. The upper ends of the plugs are in the nipple zone, but the greater part of their lower ends project into the loose connective tissue of the cutis.

There is now developed a new zone beneath the nipple zone, composed of young, round, closely packed connective-tissue cells. Surrounding and supporting the epithelial elements of the gland, these form the stroma of the gland (stroma zone).

A retrograde metamorphosis next begins in the central cells of the primary epithelial ingrowth, and from the centre the degeneration proceeds peripherally and downward. It takes the form of a cornification (Fig. 1039, *hp*) and proceeds at first very rapidly, though its final progress is so slow that sometimes it is not complete until after birth. Ultimately it leads to the complete disappearance of the primary epithelial ingrowth or mammary point.

At the same time as the primary ingrowth is degenerating the secondary ingrowth, nipple zone, and stroma zone are continuing to develop. As the secondary epithelial plugs push their way into the underlying mesodermic stroma, they become clubbed below. At the same time the originally solid plugs are hollowed out and converted into tubes, and during the seventh month of intra-uterine life, or about that time, give off numerous buds (Fig. 1039). In connection with these latter, small irregular groups of epithelial cells may be seen, the matrix of the acini. The branching of the ducts, even up to the time of birth, is but slightly advanced. At birth the milk ducts do not extend beyond the areola, and the whole gland shows an expansion of but 1 cm. and weighs only 30 to 60 cgm. (Puech).

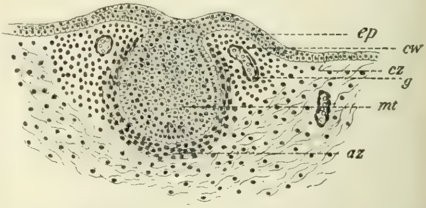

FIG. 1037.—Primitive Nipple, Club-Shaped Stage, of a Pig Embryo 6.5 cm. long. *ep*, Epidermis; *cz*, layer of cylindrical cells; *cw*, cutis wall; *mt*, mammary point; *g*, blood-vessel.

A rudimentary corpus mammæ is represented by a well-defined rounded mass, around the circumference of which the lobes project irregularly. The whole is embedded in a well-developed stroma, which is surrounded by fat lobules of the subcutaneous tissue. The coarse connective-tissue fibres of the stroma radiate from the corpus mammæ and become continuous with the fibrous capsules of the fat lobules. These latter surround but do not mix with the stroma. Beneath, the stroma is continuous with the fascia covering the pectoral muscle.

The fat layer of the skin becomes locally thickened in the region of the gland, but not until five or six years after birth does fat develop in the stroma between the gland lobules.

At birth the ducts possess a simple epithelium, cubical in the deeper parts, but cylindrical in the region of the nipple.

The time at which the various changes noted above occur varies considerably, being by no means constant. Even in the new-born the development is not always equally far advanced.

The nipple is developed in the human species toward the end of intra-uterine life. Then the mesodermic tissue which constitutes the nipple zone rapidly increases, and between the elements smooth muscle cells soon appear.

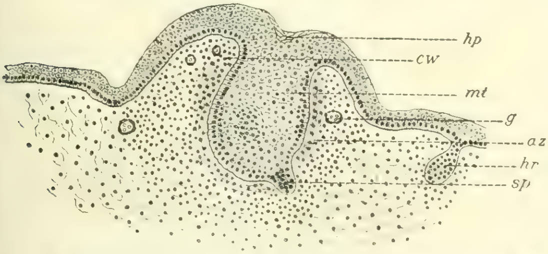

FIG. 1038.—Primitive Nipple of a 12 cm. Pig Embryo with an Epithelial Sprout (*sp*). *cw*, Cutis wall; *mt*, mammary point. (For other letters, see Figs. 1036 and 1037.)

The centre of the originally depressed gland area becomes situated upon the tip of a cone-shaped projection. The exact time of the elevation of the nipple varies, though sometimes occurring in embryonic life; yet frequently in children of from ten to twelve the depressed gland area with its surrounding wall still persists.

Although in some respects in development the mammary glands resemble the sweat glands, yet I think it is now generally conceded that in the higher mammals they represent modified sebaceous glands.

Upon the areola, sebaceous and sweat glands are developed. Rein has shown that the enlarged sebaceous glands of the areola (tubercles of Montgomery) are accessory rudimentary milk glands.

Condition at Birth.—It will be seen that the new-born of both sexes possess all the skin ingredients of the gland, and moreover the gland can secrete milk, which is called in German "Hexen Milch" (witches' milk). This occurs from the fourth to the tenth day after birth, and is accompanied by a swelling of the gland. It has been shown by Rein and others to be true milk. According to De Sinéty considerable changes take place in these first ten days, after which there is some acinous tissue resembling that which is seen in the adult. But only the main ducts are excavated.

From birth till puberty the breasts remain rudimentary, simply keeping pace with the general body growth. The intralobular ducts and beginning of the acini remain solid, and though there are some slight changes, such as the development of a few acini buds, yet the condition found shortly after birth persists.

In the male no further change, as a rule, occurs.

Changes at Puberty.—In the female at puberty an abrupt change like that affecting the entire organism takes place. This consists in further branching and growth of tubes into the surrounding tissue, and the stroma is also further developed. The fat which appeared in the stroma at the fifth to the sixth year rapidly increases in amount. Now development proceeds rapidly, but there is no distinct subdivision into the lobules, the true secreting acini being few in number. At each succeeding menstrual period a slight engorgement occurs, and it is probable that it is accompanied by increased development. At these times slight pricking sensations and pain may be felt, and in some cases a yellow secretion is expelled. Soon after puberty the breasts become very well developed, but they consist mainly of stroma and excretory ducts, with a relatively small amount of glandular tissue.

Situation.—The breasts are situated in the superficial fascia, above the pectoral muscles; as usually described they are said to extend from the second or third to the fifth, sixth, or seventh rib, and from the edge of the sternum to the fold of the axilla. These estimations are undoubtedly based upon external conformation, and of necessity, therefore, refer only to those portions of the gland which cause its projection above the surrounding surface.

Stiles, who witnessed the removal of over one hundred breasts which he had previously examined, found that the usual description takes no account of the peripheral processes, which extend in the subcutaneous tissue, often far beyond the prescribed limit. Moreover, he has shown that this holds true for nulliparæ, as well as for multiparæ, though of course the processes are much more marked in the latter. He gives the following description of the situation and relations of the breast:

It is divided by two intersecting lines, a vertical (1–2) and a horizontal (3–4), into four segments (Fig. 1040), named respectively cephalo-mesal, cephalo-lateral, caudo-lateral, and caudo-mesal. For purposes of more careful description, a second division is made by two oblique lines (5–6), and (7–8) into four other segments, cephalic, lateral, caudal, and mesal.

The vertical diameter (1–2) extends from the lower border of the second rib to the sixth costo-cartilage, where it begins to sweep upward toward the sternum. The horizontal (3–4) begins opposite the fourth rib or fourth interspace, just within the lateral border of the sternum, and extends to the mid-axillary line at the level of the fifth rib or fifth interspace. The oblique line (5–6) extends from the upper border of the third costo-cartilage, a little external to the border of the sternum, to the seventh rib a little in front of the mid-axillary line. The oblique line (7–8) begins on the third rib a little beyond the anterior axillary fold, and extends to the sixth costo-cartilage

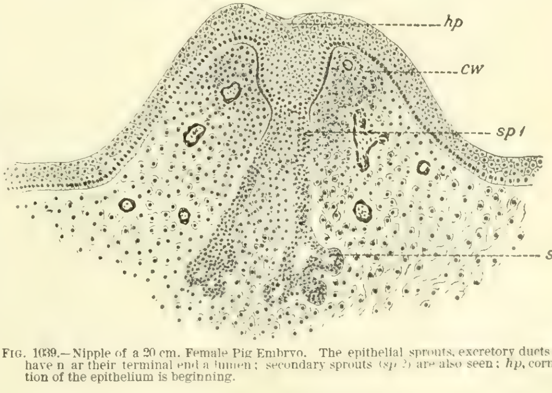

FIG. 1039.—Nipple of a 20 cm. Female Pig Embryo. The epithelial sprouts, excretory ducts *sp 1*, have near their terminal end a lumen; secondary sprouts (*sp 2*) are also seen; *hp*, cornification of the epithelium is beginning.

midway between its angle and sternal end. The circumference is obtained by connecting the extremities of the lines.

When the arm is raised, as for operation, the nipple, in nulliparæ, is opposite the fourth rib or fourth interspace and 2.5 cm. mesad to the axillary border of the pectoralis major. Thus the extent to which the breast overlaps the border of the pectoralis major is considerable. The level varies with the stature; as a rule in tall women the breast is low, while with short and broad-chested women it is high.

Relations.—The relations of the posterior surface of the breast can best be treated by describing each segment separately.

The meso-cephalic segment (Fig. 1040, A) rests entirely upon the pectoralis major; so also does the meso-caudal segment (D), except at its lower edge where it overlaps the aponeurosis of the external oblique.

The cephalic half of the cephalo-lateral segment (B) rests upon the pectoralis major, the edge of the pectoralis minor, and for a slight extent upon the serratus magnus muscles. Upon the latter and under cover of the pectoralis major it extends up into the axilla as far as the third rib. This is the axillary tail of Spence. The circumference of this segment crosses the border of the pectoralis major muscle, where its fibres leave the third rib to form the ventro-axillary fold.

The caudal half of the cephalo-lateral segment (B) and the cephalic half of the caudo-lateral (C), with the exception of a small portion near the nipple which is over the pectoralis major, lie upon the serratus magnus. The caudal half of the caudo-lateral segment (C) overlies those portions of the external oblique and serratus magnus which arise from the fifth and sixth ribs, except a portion near the nipple which is over the pectoralis major.

Thus it will be seen that, with the arm in the position assumed for operation, fully one-third of the whole breast lies caudo-lateral to the axillary border of the pectoralis major. One-half of this overlies the axilla, filled with its fatty fascia containing numerous lymph nodes. These lymph nodes appear to be in direct contact with the breast tissue.

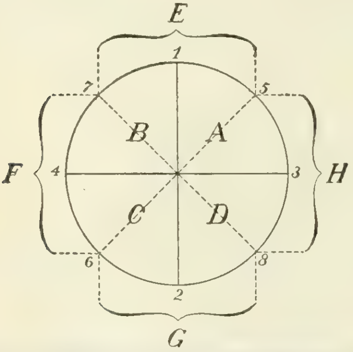

FIG. 1040.—Diagram to Show Method of Dividing Breasts for the Purpose of Description. *1* to *8*, Lines of division for the location of the different sections (see text). A, Mesocephalic; *B*, cephalo-lateral; *C*, caudo-lateral; *D*, meso-caudal; *E*, cephalic; *F*, lateral; *G*, caudal; *H*, mesal sections or divisions.

The dorsal surface of the breast is concave, composed mainly of stroma containing projecting processes of the parenchyma. The stroma is continuous with a loosely interlaced network of connective tissue which forms the pectoral fascia. This fascia sends numerous septa between the fibres of the muscle. It is quite thin and it is difficult to separate it from the muscle, particularly in spare subjects. In some it attaches the gland so closely to the subjacent muscles that movement of the arm causes considerable movement of the gland. In others it is very loose, but even with these some movement is observed when the arm is raised. In this latter loose areolar tissue spaces have been described by Chassaignac as serous bursæ (sub- or retro-mammary bursæ).

Close examination has shown that the portions of the parenchyma which project into the stroma of the dorsal surface send numerous minute processes into the retromammary connective tissue. Some of these even accompany the septa of the pectoral fascia between the muscle fibres.

The anterior surface is for the most part smooth and convex. It is covered with skin continuous with that of the surrounding surface. The skin is thin and delicate and differs from that of the ventral surface of the body only at its centre, where the raised and pigmented areola surmounted by the nipple is seen.

The circumference, although in the main circular, is more or less irregular owing to the processes of the parenchyma. There are usually three fairly well-marked cusps. The largest projects toward the upper part of the axilla and has been already referred to as the axillary tail; another, much smaller, extends toward the lower part of the axilla; the third reaches toward the sternum.

At the caudal border (Fig. 1044), the circumference of the breast, the parenchyma presents a furrow but slightly marked in young thin nulliparæ, more marked in fat women, and especially prominent in multiparæ.

The cephalic border of the circumference is as a rule ill-defined, the breast arising in a gentle slope from the surrounding tissue.

Shape.—Emaciated subjects present a flat, discoidal breast with irregular surface; well-nourished subjects a hemispherical or conical with smooth surface. In adult nulliparæ (Figs. 1044 and 1045) it is somewhat conical, due to the relatively large amount of gland substance compared with the stroma. In stout subjects the relatively greater amount of circummammary fat produces a hemispherical breast. After lactation it frequently becomes pendulous, a very marked sulcus being produced where it overhangs its base. This is due to the atrophic fatty changes which at this time affect the secreting structure and produce a flabby condition. In these cases the breast sometimes becomes almost cylindrical in shape. Rarely the base of the breast is contracted, producing a stalk. This is the pedunculated breast.

Consistence.—In the virgin and nullipara the breast is firm and elastic. It loses its consistency after having attained full activity, especially if there has been a period of nursing. In women who have had several children the breasts are soft and flabby, overhanging their base to a greater or less extent.

Weight.—In the adult nullipara the breast weighs from 140 to 200 gm.; in nursing women from 400 to 500, and in exceptional cases as much as 900 gm.

Number.—A single pair of breasts is the least number normally found in any mammal. This is the usual number in man, as also in apes and a few other animals. The largest number is found in certain of the insectivora, in whom there are as many as eleven pairs. Between these limits all gradations exist. Reduction of this number is very exceptional, but there are numerous cases on record of supernumerary breasts.

Arrest may occur in their development at any time; when it occurs very early in embryonic life the breast is entirely suppressed (amazia). This is extremely rare in the human subject, and is frequently associated with other defects in development. Williams has written two very excellent articles, one on polymazia, the other on amazia. He finds complete absence of both breasts one of the rarest anomalies; outside those occurring in acephalic monsters with deficient chest walls, only four cases are recorded in literature. Complete absence of one breast is slightly less rare. A more frequent condition is the arrest of development at a later stage leading to rudimentary but functionless organs (micromazia). This also may affect one or both sides, and as with amazia may or may not be associated with deficiencies in the sexual organs or chest wall.

Absence of the nipple (athelia) is much commoner than the above. Williams has pointed out that in these cases there is really no absence of nipple structures, but simply a failure of the embryonic gland area to become elevated. This is usually unaccompanied by other anomalies, and generally affects both breasts. The areola is rarely absent when the nipple is well developed, but with athelia the areola may be absent or slightly formed. Intermediate conditions between complete absence and the perfect nipple, due to degrees of elevation of the embryonic gland area, produce the various recorded congenital imperfections.

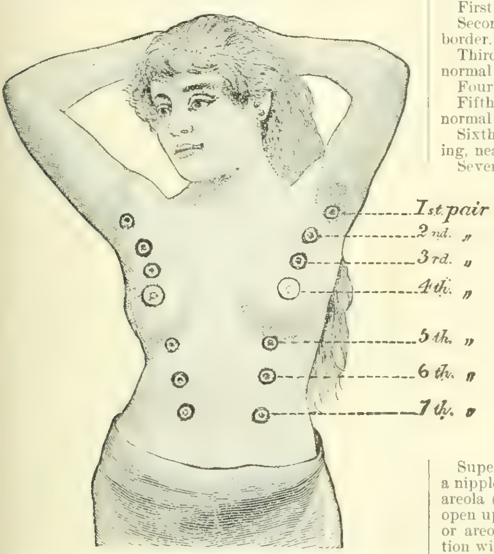

FIG. 1041.—Diagram Showing the Mammary Arrangement of Man's Early Progenitors. Williams.

Numerous records of supernumerary mammæ or nipples are found in literature. The condition is much more common than previously supposed. Bruce found in 315 individuals, of both sexes taken indiscriminately, polymastism in 7.6 per cent.; in 207 males 9.1 per cent., and in 104 females 4.8 per cent.

It has been supposed by some that any sebaceous gland may develop into a supernumerary mammary gland. There is nothing to lead us to believe that complex structures like the mammæ may be developed suddenly on any part of the body. A study of comparative anatomy and embryology seems to point clearly to an atavistic origin for their explanation. In the lemurs the inguinal and abdominal mammæ are rudimentary, only one pair of pectoral mammæ becoming developed. From them through the different types of animals, conditions are found indicating that the number of breasts is being gradually reduced.

In embryology the investigation of the development of the mammary hillocks from the mammary line, although not yet worked out in all of its stages, has been carried far enough so that we are quite sure that the conditions as found in the pig and other animals are the same in man.

By a careful study of all recorded cases Williams found that the position occupied by the mammæ in lower animals and by the mammary hillocks in embryos was the same as that occupied by aberrant mammæ. He considers that man's early progenitors were possessors of seven pairs of breasts (Fig. 1041), three cephalo-lateral to the normal, and three caudo-mesal to them.

First pair—in the pit of the axilla.

Second pair—in the middle of the ventro-axillary border.

Third pair—just cephalad and slightly laterad of the normal pair.

Fourth pair—the normal mammæ.

Fifth pair—just caudad and slightly mesad of the normal pair.

Sixth pair—caudad and slightly mesad of the preceding, near the costal margin.

Seventh pair—caudad and slightly mesad of the preceding, on the upper part of the abdomen.

Out of 166 cases collected by Leichtenstern and Bruce, there were only 4, 2.41 per cent., which could not be assigned to one or another of these positions. These mammæ erraticæ are supposed to be due to reversion to the ancestral characters much more remote than those given above.

The following table of 105 cases recorded by Leichtenstern shows the relative positions of the accessory mammæ. On the anterior side of the thorax, 96 cases (91 per cent.); in the axilla, 5 cases (4.7 per cent.); on the back, 2 cases; over the acromion, 1 case; over the outer side of the hip, 1 case. Of those on the anterior side of the thorax 94 per cent. were developed caudad of the normal pair and in a converging position.

Supernumerary mammæ often are represented only by a nipple, which may or may not be surrounded by an areola (true polythelia); or the duct of the gland may open upon the surface by one or more openings, no nipple or areola being present; or there may be no communication with the surface whatever. Rarely the extra gland is perfectly developed and functional.

Rudimentary breasts cephalad of the normal ones are rare—but 12 out of 166 cases, or 7.2 per cent. Abdominal mammæ are very rare. In polymazia the normal pectoral mammæ are aways present in their proper position and well developed. Of Leichtenstern and Bruce's 166 cases, there was only a single extra structure in 112, or 67.4 per cent.

Out of 2,189 men recruited in the military district of Donaueschingen 62 were found with one supernumerary teat and 4 with two—that is, 1 case in every 33, or 3 per cent. Besides, 48 others were found who showed discrete pigmented patches symmetrically placed upon the line usually occupied by supernumerary mammæ or nipples. These represented small areolæ.

Supernumerary mammæ are more often found on the left than on the right side. So also in amazia, the right mamma is more frequently absent than the left.

Anomalies arising late in the developmental process lead to two nipples on one areola (intra-areolar polythelia); or two on one breast (intramammary polythelia).

Supernumerary mammæ or nipples are probably found in all races. They have been noted by Owen in the orang and by various observers in many animals. Women with more than one breast are no more liable than other women to bear twins. Supernumerary mammæ appear often to be hereditary. In 7 out of 92 of Leichtenstern's cases, or 7.6 per cent., there was a history of such condition in near relatives. It is not usually associated with other malformations.

Size and Volume.—The breast, which at birth measures but 10 mm. in diameter, increases but little until after puberty, when it rapidly attains a diameter of 100–130 mm. and a thickness of 50–60 mm. The greatest length is parallel to the border of the pectoralis major.

Soon after impregnation it again increases in volume, and although it decreases somewhat at the fourth or fifth month, it becomes greatly enlarged again at the end of gestation. The second or third day after delivery the milk begins to be secreted, and now the true functional activity of the gland is first established. The milk accumulates in the alveoli and in the excretory ducts. The gland becomes harder, heavier, and more voluminous. It soon acquires a volume two or three times that of the gland before pregnancy.

After lactation it returns again to its ordinary size, which it retains until another pregnancy and another period of activity. It is now less smooth, firm, and elastic than the virgin mamma.

After the menopause the useless gland with the rest of the genitals becomes atrophied. The glandular and secreting structures are frequently replaced by fat, when but little reduction in size occurs. In other cases this does not occur, and the entire gland is reduced to a small fibrous area around the nipple and immediately beneath the skin. Thus it returns at last to a condition approaching the infantile.

The two breasts are seldom equal in size, the left usually being the larger, sometimes quite considerably. This is thought to be due to the fact that women nourish the child more on that side.

The size of the breasts presents considerable ethnological variations. Huschke says that, as a rule, they are more voluminous in warm than in cold countries, and in moist countries and in valleys than in dry countries and mountains. As regards races, variations are considerable, the people of southern Africa being remarkable for their large and pendent breasts.

In individuals, the size of the breast offers considerable variations. It appears that the development is independent of the build and constitution; large, robust women are frequently seen with very poorly developed breasts, while, on the other hand, small women are seen with large, well-formed breasts.

The mammæ are formed of stroma containing fat and the essential gland structure. It is therefore clear that size alone will not determine the activity of the gland. A breast may be formed of a maximum amount of stroma and a minimum amount of parenchyma (fatty mammæ), or of a maximum amount of gland tissue and a minimum amount of fat (glandular mammæ). For this reason large breasts may furnish much less milk than much smaller ones.

De Sinéty has pointed out that city-bred women are likely to have breasts much more poorly developed and functionally less active than their country sisters. This he attributes to the social conditions in the city leading so often to the wet-nurse and bottle, and he believes that this, carried through several generations, has led to an inherited characteristic. Thus the breast is following the law of morphology, that those organs which have become functionless and useless gradually are less and less developed and finally disappear.

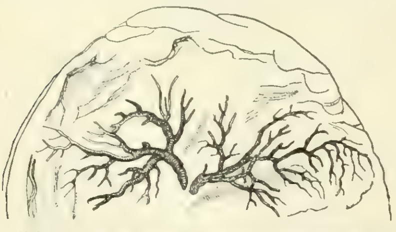

FIG. 1042.—A Part of the Ventral Surface of the Corpus Mammæ, Showing the Branchings of Two Milk Ducts. (Henle.)

Structure.—The breasts are composed essentially of three parts: first, the mamma proper; second, the covering skin; third, the surrounding fatty tissue. The mammæ, like all glands, consist of two parts: the parenchyma, and the stroma. The latter includes the fat, which is embedded in it, also the blood-vessels, lymphatics, and nerves, which ramify through it. The parenchyma is divided into a central compact part, the body or corpus mammæ, surrounded by peripheral processes. It is made up of lobes (lobi mammæ) divided into lobules (lobuli mammæ). All of the lobules of a lobe empty by small into larger ducts. These ultimately lead to one large duct (ductus lactifer), which opens upon the nipple (papilla mammæ) (Figs. 1042 and 1043).

When the covering parts are removed, the gland presents a flattened mass with an irregular, circular outline, thicker in the centre than at the periphery. The ventral surface is convex but quite uneven, due to the processes which project toward the skin. The thick central portion mentioned above is the corpus mammæ, and upon the size and extent of this the external conformation of the breast depends. The dorsal surface, as already noted, is flat or slightly concave and much less irregular than the ventral surface (Figs. 1044 and 1045).

The circumference is quite thick and well defined, but it is thicker below than above (Fig. 1044). When a section is made through the nipple, the cut surface of the corpus mammæ appears triangular. The apex of the triangle is at the nipple, and the base, which represents the dorsal surface, rests against the thorax, from which it is separated by the stratum of loose areolar tissue.

Extending from this central compact area of glandular tissue, the peripheral processes reach in all directions. As already noted, there are three main cusps: one extends cephalad toward and into the axilla; another caudad of the axilla; while the third reaches toward the sternum. Besides these large processes there are numerous small ones, which radiate in all directions around the circumference. These form numerous branched, interlacing processes enclosing and surrounding masses of fat.

From the ventral surface triangular processes project toward the skin (7, Figs. 1044 and 1045), and from the apex of the triangle the connective tissue covering the gland is prolonged to the dermis. In thin women the parenchyma at these points reaches almost to the surface.

From the dorsal surface, much more delicate processes project into the retromammary tissue, even reaching through this and extending into the pectoral fascia to get between the fibre bundles of the pectoralis major. These processes are very minute and are often overlooked.

Both body and processes are completely covered by a delicate connective tissue. Those parts of this which cover the scattered branched parts of the gland are continuous with the surrounding subcutaneous tissue. It is too delicate to be deserving of a separate name, but has nevertheless been called by some the fibrous capsule of the mammæ.

Stroma.—The stroma is tough and compact, but soft and yielding. It is white in color and is composed of coarse, wavy fibres. In the nullipara, there is only here and there an isolated fat lobule; consequently the fibres are closely arranged. In the multipara, much more fat is found in the stroma. Toward the periphery more fat lobules are seen, and the stroma of the peripheral processes becomes directly continuous with the connective-tissue framework of the fat lobules.

As stated above, from the apex of the processes on the ventral surface, the stroma is continued to the corium. These prolongations have received the name of ligaments of Cooper (7, Figs. 1044 and 1045).

Between the ventral processes of the gland, and therefore surrounded by the ligaments of Cooper, are supramammary accumulations of fat (adipose fossæ). On the dorsal surface of the gland are other fat spaces (retromammary fat) (9, Figs. 1044 and 1045). This is separated from the pectoral fascia by loose connective tissue, and in it one or more large lymph spaces are found, the retromammary or submammary bursæ. The subcutaneous fat and that between the lobules give the smoothness to the surface of the gland, and when it is absorbed, as during lactation or in emaciation, the lobules of the gland stand out much more distinctly.

Under the nipple and areola, the stroma contains no fat. Its fibres are here very loosely arranged, and allow free mobility of the nipple. It is this also which allows the distention of the ducts and sinuses during lactation.

Parenchyma.—The relative amount of parenchyma to the stroma varies in different nulliparæ, also even in the same breast one lobe or section may have numerous well-developed lobules, while another has few or none, these remaining almost as at puberty merely branching ducts. The parenchyma, on close inspection of a cut surface of fresh gland, is seen to be made up of closely packed sago-like grains.

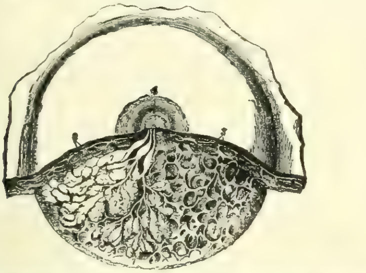

FIG. 1043. Dissection of the Lower Half of the Female Mamma during the Period of Lactation. (Luschka.) *a*, *a*, *a*, Undissected part of the mamma; 1, the mammilla; 2, areola; 3, subcutaneous masses of fat; 5, three lactiferous ducts passing toward the mammilla where they open; 6, one of the sinuses or ampullæ; 7, some of the glandular lobules which have been unravelled; 7′, others massed together. (Quain.)

Ducts.—The ducts are also seen in a cross section, running through the nipple to its summit, where they open. Arising from the acini the minute ducts unite to form larger canals, so that each lobule gives rise to a single duct (lobular duct) (Fig. 1043). These join to form larger and larger ducts until but one duct leaves each lobe. This is known as the galactophorous or lactiferous duct. These, fifteen to twenty in number, corresponding to the lobes of the gland, gather at the nipple, through which they pass, in a vertical direction, to open upon its summit. Beneath the areola, each duct presents an irregular, fusiform swelling 12 to 15 mm. long and 6 to 8 mm. wide, known as the sinus or ampulla (Fig. 1043), also as the sacculus or reservoir. Secondary ampullæ occur here and there on the ducts. In the ampulla and the large ducts, milk accumulates in the intervals between nursing. Beyond the sinus, the ducts are reduced in size and collected into a bundle, the largest ones occupying the centre. Side by side, surrounded by muscle, areolar tissue, and vessels, and without communicating, they pass to the summit of the nipple. Here separately by minute orifices, they open into the bottom of depressions. The orifices, which measure 6 mm., are distinctly smaller than the ducts. In the loose areolar tissue under the areola, the ducts and sinuses receive minute ducts from the adjacent lobules.

The ducts are composed of two coats, an external and an internal. The external coat is formed of white fibrous tissue intermixed with longitudinal and circular elastic fibres. Smooth muscle fibres have also been described. They are said to be particularly abundant around the ampullæ, where they form an imperfect sheath. The inner coat is formed of epithelium resting on a basement membrane. The epithelial cells, constituting a single layer, are flat in the lobular ducts, becoming cubical in the larger ducts, and columnar in the lactiferous ducts and ampullæ.

Lobes, Lobules, and Acini.—Each of the fifteen to twenty ducts is the outlet for a single lobe of the gland. Each lobe is of a reddish cream color and rather friable, and is a compound tubo-racemose gland. Although each lobe is in contact on either side with the neighboring lobes, there is no known communication between them. The lobes are separated, by a considerable amount of areolar tissue, into lobules, which in turn are made up of acini (Fig. 1043).

The acini are small, spherical, or pyriform masses, measuring on an average 0.13 to 0.15 mm. in diameter. An acinus consists of a minute sac lined by a single layer of small granular epithelial cells (Fig. 1046 and 1047) resting on a delicate hyaline membrana propria. This latter completely envelops the acinus, and is continued for a short distance on the minute excretory duct, with which the acinus connects. The above is the condition in a gland which has not yet become active.

With the beginning of lactation an acinus enlarges, and becomes distended with a clear, slightly viscid yellowish secretion (Fig. 1047). Its cells are flattened against the membrana propria, and contain fat globules of varying sizes.

The fluid in the acini is the colostrum. It is produced for the first two to three days after delivery, when the free secretion of milk is first established. Besides serous fluid, colostrum is composed of fat globules of varying size, similar to those found in normal milk but somewhat larger and having a tendency to agglutination; also of granular cells, spherical or oval in shape, having a diameter or from 3 to 25 μ (colostrum corpuscles). The cor-

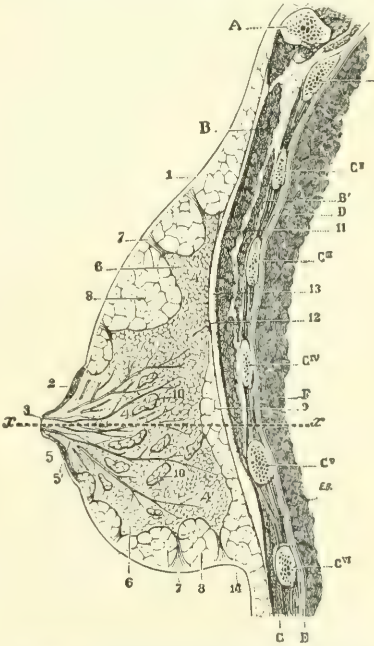

FIG. 1044.—Vertical Ventro-dorsal Frozen Section of the Right Breast of a Woman, Twenty-two Years Old. (C^{I}–C^{VI}, First to sixth ribs; A, clavicle; B, pectoralis major; B′, pectoralis minor; C, external oblique; D, intercostals; E, pleura; F, lungs; 1, skin of breast; 2, areola; 3, nipple; 4, mammary gland, central part; 4′, peripheral part; 5, milk ducts; 5′, sinus; 6, cusps of the mammary gland; 7, ligaments of Cooper, continued to the skin; 8, fat lobules; 9, fatty retromammary pad; 10, intramammary fat; 11, aponeurosis of pectoralis major; 12, superficial fascia forming suspensory ligament of breast; 13, layer of loose areolar tissue between superficial fascia and subjacent serous aponeurosis of the breast; 14, submammary furrow. (Testut.)

puscles consist of a mass of fat globules surrounded by protoplasm.

By some these are considered to be fatty-degenerated leucocytes, by others the central cells of the originally solid acini, also fatty-degenerated. The subject has led to much controversy and is by no means settled.

When fully active the acini secrete true milk. The protoplasm in the cells becomes broken up and displaced toward the outside by the accumulation of oil drops (Fig. 1048 and 1050). The minute oil drops, at first separate, become confluent, forming larger globules which occupy the greater part of the entire cell. There are two main ways of explaining the liberation of these oil globules into the lumen of the acini.

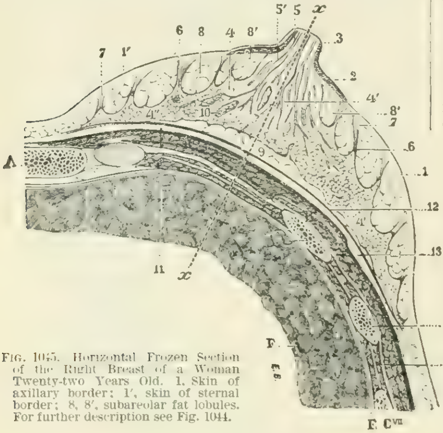

FIG. 1045. Horizontal Frozen Section of the Right Breast of a Woman Twenty-two Years Old. 1, Skin of axillary border; 1′, skin of sternal border; 8, 8′, subareolar fat lobules. For further description see Fig. 1044.

According to the first, the mammary gland is similar, functionally, to a sebaceous gland. The glandular cells are believed to multiply constantly during lactation. The cells in the deeper layer replace, toward the lumen of the acini, those in a superficial layer, and these becoming filled with fat globules degenerate and break down.

According to the second, the fat globules as they accumulate in the cell force the nucleus with its surrounding protoplasm against the basement membrane. The fat globules continue to accumulate until the tension within the cell is so great that its membrane ruptures into the acinus, liberating the superficial fat and protoplasm. But the cell itself is not, as a rule, cast off. The protoplasm accumulates again around the nucleus, the cell wall is again formed, fat globules accumulate again and the process is repeated. It seems probable that after numerous repetitions the cell becomes worn out and is cast off, to be replaced by a new cell.

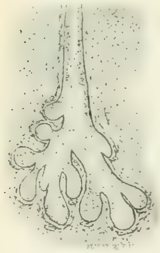

FIG. 1046.—Terminal Branches of a Milk Duct from the Breast of a Young Woman. (Bardeleben, × 56.)

Within an acinus the cells are cubical, or even columnar and of very unequal size. Some are found large, distended with fat projecting into the lumen, others small, consisting merely of a nucleus and so little fat that it is obscured by the protoplasm. Between these are all grades.

During lactation the acini have a comparatively wide lumen, the epithelial layer forming but a thin lining to the irregular tubular or spherical spaces.

At all times there are numbers of mast cells in the connective tissue surrounding the lobules. During lactation these are immensely increased. They have been supposed to have some connection with the secretion of the milk, but their exact function is not yet known.

The milk which distends the acini during full functional activity consists of fat droplets which were present in the cells, and débris of disintegrated protoplasm floating in a clear albuminous fluid (milk plasma). The milk globules from 2 to 5 μ in diameter do not coalesce owing to a delicate sheath of casein, Acherson's membrane.

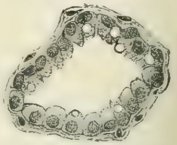

FIG. 1047.—Mammary Gland of the Dog. Transverse section of a terminal vesicle, showing an early stage of the formation of fat globules. (Heidenhain.)

During pregnancy and lactation, the increase in the size of the gland is due to increase of the parenchyma. This consists of an increase in the size and number of the lobules. Finally they increase so much that they touch and cause a disappearance of fat between them. At this time on section the naked-eye appearance closely resembles that of a salivary gland. Moreover, at this time the superficial fat becomes absorbed, and the vessels become dilated and their walls thickened. The breast, due to the rapidly growing acini, presents to the hand an uneven feeling. The acini increase first on the peripheral processes, thence along the larger ducts toward the centre of the corpus mammæ.

After lactation the breast returns to a resting stage. The parenchyma undergoes involution, and fat is developed in the stroma. The acini are reduced to narrow tubules, many becoming atrophied. The gland does not regain its virgin appearance; therefore it is easy to tell an involuted multiparous from a nulliparous breast. The corpus mammæ is loose, irregularly broken up, and less distinct. The peripheral processes are larger, with a more extensive distribution. It is therefore easy to separate the corpus mammæ from them. The stroma is loose, and contains numerous fat lobules. The whole is less smooth, firm, and elastic; therefore it tends to be pendulous, and a sulcus is formed where it overhangs its base. With each succeeding pregnancy a new period of activity is followed by involution.

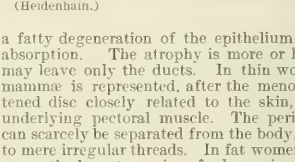

FIG. 1048.—The same Anatomical Relations as are shown in Fig. 1047. The gland, however, is in its highest stage of functional activity. (Heidenhain.)

With the end of the sexual activity a gradual permanent atrophy of the secreting portion of the gland begins. This occurs, according to Stiles, by a fatty degeneration of the epithelium followed by its absorption. The atrophy is more or less complete and may leave only the ducts. In thin women, the corpus mammæ is represented, after the menopause, by a flattened disc closely related to the skin, and also to the underlying pectoral muscle. The peripheral processes can scarcely be separated from the body, and are reduced to mere irregular threads. In fat women after the menopause the breast remains of a large size, but is composed almost entirely of fat. A few ducts, here and there, form a wide meshwork except in the neighborhood of the nipple, where there is a flattened disc of gland tissue.

The skin covering the ventral surface of the breast, except at its centre, does not differ from that of the adjacent thorax. It is thin, flexible, and very adherent to the subjacent fatty tissue and covered with minute hairs and rudimentary sebaceous glands. Following pregnancy the skin is sometimes marked with bluish or whitish striæ similar to those of the abdomen.

In the centre of this skin is the areola surmounted by the nipple. The skin of the areola is thinner and more delicate than that surrounding it (Fig. 1051, A). It is pigmented and marked by numerous well-developed sebaceous glands. Its under surface is devoid of fat, but contains numerous unstriped muscle fibres. The areola measures 15×35 mm. in diameter. Its color in nulliparæ is a rosy pink, whose shade differs with the complexion of the individual.

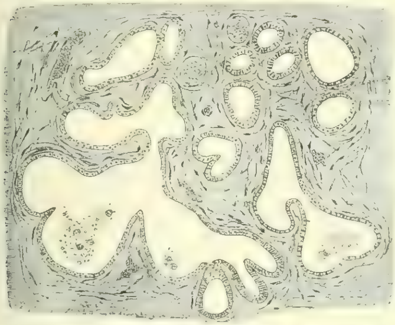

FIG. 1049. From a Cross Section of the Corpus Mammæ of a Woman who Died during Childbirth, showing the Cubical Epithelium of the Tubules. (Bardeleben, × 116.)

In the second month of pregnancy the areola begins to enlarge and darken. This increases as pregnancy advances and serves as one of the signs of gestation. After lactation the color fades, but seldom entirely disappears. In dark brunettes, during pregnancy, the pigmentation becomes very dark, almost black, and following lactation considerable pigment remains. In light blondes, on the other hand, the darkening of the areola is very slight and may subsequently almost entirely disappear. In the fifth or sixth month of pregnancy there is sometimes seen around the areola an irregular slightly pigmented ring, the secondary areola (Fig. 1051, B).

The ventral surface of the areola is roughened by numerous slight elevations. These are caused by well-developed sebaceous glands, areolar glands. At the centre of each a minute lanugo hair marks its opening. During pregnancy these glands enlarge markedly, forming hemispherical elevations from 2 to 5 mm. in diameter. They are now known as the tubercles of Montgomery (Fig. 1051). They are particularly numerous and well marked in the secondary areola (Fig. 1051, B). Toward the end of gestation they become very active, their peculiar fatty secretion keeping the areola moist and serving to protect it during suckling.

The sudoriferous glands of the areola are remarkable for their large size and degree of convolution.

Besides the above there are from five to fifteen accessory milk glands below the areola. They vary considerably in size, and open on the summit of the nipple. The areolar muscle proper is thickest beneath the nipple and fades toward the circumference of the areola (Fig. 1044). It is composed mostly of circular fibres among which are mixed certain radially disposed bundles. All are attached to the skin, making it therefore a skin muscle analogous to the dartos.

The Nipple.—The nipple is situated a little meso-caudad of the centre of the breast on a level with the fourth rib or over the fourth intercostal space and about 12 cm. from the midline (Figs. 1044 and 1045). Developed from the gland area, in the third year it projects from the surface, and soon becomes conical or cylindrical. It attains its full size shortly after puberty. In some cases it is hemispherical, flattened, or discoidal, or with apex larger than base, pedunculated. It is about 10 to 12 mm. long, with a diameter at the base of 9 to 15 mm., and points ventrad and slightly laterocephalad. Its tip is rounded and marked by fifteen to twenty minute depressions, milk pores, into which the lactiferous ducts open. These form the cribriform area. In some cases the nipple is retracted into a depression and projects only on response to stimuli. The skin of the nipple (Fig. 1051, 1), thin and pigmented like the areola, is remarkable for the number and size of its papillæ. It possesses neither hair follicles nor sweat glands, but near the base are a number of sebaceous glands.

The muscle fibres of the areola are continued up into the nipple, being separated from the skin below only by the sebaceous glands. They form a layer composed almost exclusively of circular fibres. From the inner side of this layer numerous muscle bundles are given off. These cross and recross and form a sort of trellis around the lactiferous ducts. Under the influence of cold, emotion, or touch these contract, causing circular folds in the skin of the areola, and causing the nipple to become firmer and more projecting. Besides causing this erection of the nipple, the rhythmical contraction of the fibres tends to force the milk from the distended milk ducts and sinuses into the area cribrosa. If the fibres contract spasmodically, they act as a sphincter and retain the milk. Another set of fibres take their origin from the deep connective tissue below the nipple and end upon the under surface of its skin. They pass in variously-sized bundles through the connective tissue which surrounds the milk ducts. Contraction of these fibres causes the nipple to retract.

During pregnancy the nipple becomes larger, more readily erectile, and more sensitive. Suppression and multiplication of the areola and nipple were considered with suppression and multiplication of the gland proper.

Arteries.—The arteries which supply the breast are derived from three sources: from the internal mammary, from the lateral thoracic (long thoracic), and from the intercostal. The internal mammary, a branch of the subclavian, is the principal artery of the breast. It gives off two or three branches (rami perforantes), which pierce the chest wall and then pass to the cephalo-mesal edge of the gland, where they break into branches for both of its surfaces. The lateral thoracic, a branch of the axillary, gives two or three branches (external mammary rami) to the external portion of the breast. Besides the above, twigs from the pectoral rami of the acromial thoracic artery pierce the major pectoral and supply the cephalic segment of the breast. Lastly, the intercostal furnishes sev-

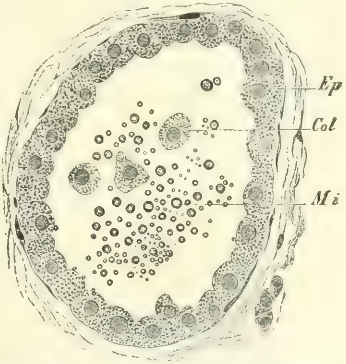

FIG. 1050.—Transection of a Tubule of the Corpus Mammæ. *Ep*, Glandular epithelium; in the lumen are milk globules and colostrum corpuscles. (Bardeleben, × 400.)

eral small, short branches to the caudal segment and posterior surface. The above vessels, taking a sinuous course, break up into numerous branches which anastomose freely and ramify in the fascia surrounding the gland. From the wide-meshed, irregular network of the ventral surface two sets of branches are given off: one very small to the skin, the other much larger to the gland proper. These latter, situated in the stroma, divide and subdivide on the connective-tissue framework. They finally form a close capillary network which surrounds the acini. The arterioles of the nipple do not form cavernous sinuses, and its erection is due entirely to the muscular tissue.

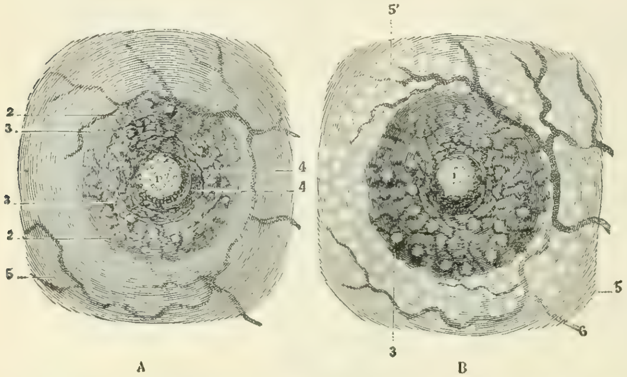

FIG. 1051.—The Nipple and its Areola. A, In a non-pregnant; B, in a pregnant woman. 1, Nipple; 2, areola; 3, tubercle of Montgomery; 4, sulcus at the base of the nipple; 5, skin of breast; 5', secondary areola; 6, venous circle of Haller.

Veins.—From the arterial capillary plexus around the acini a venous plexus arises. This proceeds toward the ventral surface of the gland and forms beneath the skin a large-meshed plexus. During the period of lactation these vessels are seen through the skin as blue lines. Around the nipple, these subcutaneous veins form a more or less complete ring, the venous circle of Haller (Fig. 1051, B).

The superficial network communicates freely with the superficial veins of the neck above, with those of the abdomen below, and with the thoraco-epigastric vein laterally. These carry the blood into the subclavian, the intercostal, the internal mammary, and the axillary by branches which parallel the arteries.

Lymphatics.—The following description of the lymphatics is in the main that given by Stiles, and differs somewhat from that of other authors. There are five sets of lymphatic vessels: (1) superficial or cutaneous, including those of the nipple, areola, and surrounding skin; (2) subareolar plexus (Sappey); (3) intramammary; (4) those of the circummammary fat; (5) retromammary.

The cutaneous lymphatics are similar to the cutaneous lymph vessels elsewhere. It is to be noted that those of one side of the body communicate with those of the other; thus explaining the occurrence of axillary infection on one side from a tumor of the opposite. Upon the skin of the nipple and areola the network formed by these vessels is very close, being particularly rich upon the nipple. They open mainly into the subareolar group.

The subareolar lymphatics consist of very large vessels, forming a wide-meshed network running horizontally in the loose areolar tissue around the lacteal sinuses. As noted above, the cutaneous vessels open into this plexus, as do also many of the intramammary vessels. It thus serves as a means of communication between the two. From the subareolar plexus of lymphatics Sappey states that there are two and sometimes three large trunks which open into the axillary lymph nodes.

The intermammary lymphatics begin as a plexus of small channels consisting of a single layer of endothelium supported by stroma. Each mesh of the network surrounds one or more of the ultimate lobules of the gland, and receives its lymph from the interacinous spaces. From this layer vessels parallel to the milk ducts proceed to the subareolar plexus into which they empty.

These periductal as well as the perilobular lymphatics anastomose with others which are closely related to the blood-vessels. The larger blood-vessels are accompanied by two or more lymphatics which occupy their sheaths. The smaller vessels are usually accompanied by only one lymph channel, which is larger than the vessel and more or less completely surrounds it.

The circummammary set receives branches from the skin and the ventral surface and circumference of the breast. It is merely a part of the general lymphatic system of the ventral chest wall. From this set larger lymph vessels proceed between the layers of the deep fascia. They soon pierce the deep layer of this fascia and proceed, as large muscular-walled lymph vessels, to the lymph glands.

The retromammary lymphatics include those of the pectoral fascia. They receive branches from the posterior surface of the gland. Either directly or indirectly some of the lymph from all other sets passes into these lymphatics of the deep fascia which accompany the mammary blood-vessels and thus reach the lymph nodes.

The lymphatics of the inner part of the gland accompany the branches of the internal mammary artery through the chest wall and empty into the sternal lymph nodes situated along this artery. A great many accompany the branches of the axillary artery to empty into the axillary lymph nodes. The retromammary lymphatics of the two breasts communicate.

During the activity of the breast the lymphatics are filled and the lymph nodes are red, solid, and composed almost entirely of lymphoid tissue. During inactivity the lymph vessels are but slightly filled and the nodes appear to take on a fatty change. This is particularly marked in senility.

Nerves.—The nerves of the breast, excluding those derived from the sympathetic, which enter the gland with the arteries, are derived from three sources: first, from the second, third, fourth, fifth, and sixth intercostals; second, from the cervical plexus; third, from branches of the brachial plexus. The intercostals supply the breast by twigs from their anterior and lateral cutaneous branches. The third and fourth cervical nerves of the cervical plexus give off the suprasternal, supraclavicular, and supra-acromial. Twigs from the middle of these groups, the supraclavicular, supply the upper part of the breast. From the inner and outer cords of the brachial plexus the internal and external anterior thoracic nerves take origin and pass forward to supply the pectoralis major and minor muscles. Twigs from these nerves pierce these muscles to supply the breast on its under surface. These nerves receive their fibres from the anterior primary divisions of the sixth, seventh, and eighth cervical and first thoracic nerves. They proceed to the gland proper, to the skin, to the muscle fibres below the areola as well as to the blood-vessels. On and around the areola some of the nerves end in Pacinian corpuscles, and in the nipple they may end in tactile corpuscles in the papillæ.

Stimulation of the mammary nerves causes an erection of the nipple, dilatation of the vessels, and secretion of milk. After section of the cerebro-spinal nerves erection of the nipple does not occur, but the secretion of milk is not interfered with. It seems probable that there are special nerves, aside from those of the blood-vessels, governing secretion; but this has not been proved. Emotional disturbances (anger, fear, and so forth) arrest secretion.

From 500 to 1,500 c.c. of milk is daily secreted. To remove this from the gland there is not only the mechanical action of sucking, but also the activity of the gland itself. This latter consists in the contraction of the muscle fibres beneath the areola. By these the nipple is erected and by their rhythmical contraction the milk ducts and sinuses are emptied. The sucking not only stimulates the muscle to act, but also excites the sensory nerves of the nipple, thus causing a reflex stimulation of the gland acini and an increase of the secretion. During activity the vessels of the gland are dilated. The amount of the secretion appears to be influenced by blood pressure. Frequent and rapid emptying of the gland causes a greater flow, possibly through secretion pressure within the cells. The oftener the breasts are emptied the richer the milk becomes in casein. The last milk obtained at any time is always richer in fat, as it comes from the acini.

Human milk is always alkaline. Cow's milk may be alkaline, acid, or neutral. The milk of carnivora is always slightly acid. Various substances, when eaten by the mother, are secreted in the milk. Such are anise, vermouth, garlic, etc.; chloral, rhubarb, opium, iodine, mercury, lead, etc. Some substances, such as atropine, arrest the secretion of milk.

Milk contains large amounts of casein, lactose, and fat, also certain inorganic constituents. Neither the casein nor the lactose occurs in the blood, and fat is found only in small amounts. The inorganic salts in the milk are in different proportions from those found in the blood. Food rich in proteids increases the amount of milk, but the relative amount of fat is increased more than the other constituents. With a pure flesh diet, the milk contains a very large amount of fat. Fat added to the food, if not accompanied by an addition of proteid material, rather diminishes than increases the amount of fat in the milk. It appears, therefore, that the fat in the milk is not obtained from the fat taken with the food, but is the result of the decomposition of the proteid. Increasing the carbohydrates of the food does not increase the amount of sugar in the milk. The greatest part of the sugar is therefore also derived from the proteids; so too is the casein. Both the milk sugar and the casein are probably formed by the action of ferments which remain in the cells and do not pass into the milk. It is clear that milk is a chemical product, and that it is due to the activity of the cells in the mammary gland. Concerning the specific chemical source of the constituents, nothing is known with certainty. The relative proportion of the various constituents of the milk varies in the different months after delivery. The cause of this variation is not known, but by it those substances best suited to the child during its different periods of growth seem to be supplied.

Abram T. Kerr.

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BREAST, FEMALE, DISEASES OF THE.

—AMAZIA.—Entire absence of mammary glands is extremely rare, and is accompanied by other deformities usually incompatible with life. Absence of one breast is more often met with, and the corresponding ovary is found to be wanting as well (Scanzoni), or the great pectoral muscle of the same side. Probably absence of one breast and deformity of the other is the nearest approach to amazia found in the adult. A rudimentary breast may be so small as to justify the term micromazia.

POLYMASTIA.—Supernumerary mammæ are not uncommon. Bruce,[1] in 4,000 examinations, found this deformity present in 1.54 per cent., a ratio greater than usual, I believe. He also finds men more often affected than women, in the proportion of 4 to 1, a result contrary to that obtained by Godfrain.[2] I have seen the deformity more often in females. Axillary prolongations are not infrequently met with, and may be mistaken for lymphatics. They undergo the usual development during pregnancy, the secretion escaping by the nipple. Supernumerary mammæ occur most frequently in pairs, and are situated below the normal glands, rather nearer to the middle line of the body; the situation next in frequency is above the normal glands and further from the middle line, *i.e.*, toward the axilla. When the deformity is unilateral, the left side is most often chosen. Supernumerary glands below the normal mammæ are larger and better supplied with nipple and areola than when situated on the side toward the axilla. They of course follow the evolution of the natural gland, becoming most apparent during lactation, and undergoing atrophy after the menopause. Klob has recorded an additional mamma, on the shoulder, the size of a nut; it was provided with a nipple. Two examples have been noticed on the back. Robert reports an instance upon the thigh; Percy, one upon the epigastrium. Multimammæ are not over fecund, and may or may not be provided with nipples for the additional glands, or the secretion may escape by a small opening. Functionally also there may be great variation. Ross[3] reports a mulatto with a third breast beneath the normal left one. It was six inches in circumference, was provided with nipple, follicles, and areola, yielded milk, and if not attended to was painful from overdistention. The nipple was too small for the child to nurse. Lynceus[4] reports a woman with four breasts in two vertical lines. All gave milk abundantly. Gardner[5] mentions a similar case in a negress, the supernumerary glands being in the neighborhood of the axillæ. Percy[6] reports the case of a vivandière who had four mammæ in two vertical lines, and a fifth five inches above the umbilicus, in the middle line. This latter resembled the breast of an impubic girl; the other four secreted milk.

Alexander[7] records the case of a mulatto male with six nipples in two vertical lines, there being a distance of four inches between the nipples vertically. The subject of the report stated that his mother was malformed in like manner, four of her nipples giving issue to milk;

also, that, of several brothers and one sister, all save one brother were provided with four supernumerary breasts. Unfortunately, these statements could not be verified by an examination. Robert's[8] case, already referred to, is as follows: A woman, whose mother had three breasts, herself had a supernumerary mamma upon the outer surface of the left thigh, four inches below the great trochanter. Her own child sucked the additional mamma for twenty-three months. Four foster-children nursed from it during six years. Robert examined this mamma and found it atrophic like the (pectoral) others, the menopause being past. Handyside[9] reports three brothers each with four mammæ. The parents were normal. Variations, both as regards nipples and areolæ, are observed to occur, not only in connection with additional breasts, but also with mammæ in the usual situation and otherwise normal. G. Honnaüs saw five nipples to one breast. Imperfectly developed nipples, or indeed entire absence of nipples, is more common, and this condition is the cause of much pain and inconvenience, owing to the infant being unable to nurse properly, and so inducing engorgement, with consecutive inflammation of the corresponding mamma. Congenital abnormalities of the mamma are hereditary. They have been seen, according to my experience, more often in the negro and mulatto than in the white race.

Hypertrophy of the Mamma.—Hypertrophy of the mamma is seen in both sexes, occurring in one or both glands. Lymphatic and scrofulous persons are more likely to be so affected. As a sequel of mumps, it may accompany atrophy of the corresponding testicle. Olphan[10] quotes from the records of the Société de Biologie the case of a man who lost a testicle from cancer, and subsequently died from a recurrence of the disease. One breast was enlarged, and showed, on microscopic examination, colostrum and milk globules. Gorham[11] records the following case: The patient, a soldier, received injuries in battle, and acquired Pott's disease of the upper dorsal and lower cervical vertebræ. Atrophy of the testes was observed, and coincidently progressive enlargement of both breasts took place. Sexual desire was in abeyance after the spinal injury. Four and a half years subsequent to the accident, Gorham says: "Each breast is at this period the size of an orange, glandular to the touch, and pendulous." Prior to the spinal hurt, the patient had three children by his wife; subsequently, his figure and appearance changed, resembling that of an eunuch. This case appears to be the one previously reported by Thompson.[12] Unilateral hypertrophy has not been noticed coincidently with nondescent of one testicle. Petrequin (Labarraque: Thèse de Paris, 1875) saw a man with a pendulous mamma, 48 cm. long; no cause discoverable. Enlargement of one breast in young boys has been noted as occurring without cause, but such increase may be simulated by retromammary lipoma, as in the instance recorded by Lobker.[13]

Hypertrophy of the mamma in the female has been noticed a number of times. Inasmuch as there are physiological variations in the size of the mamma, it is not easy to say just when enlargement becomes pathological. The breasts have been found to weigh many pounds, constituting enormous tumors pendent from the front of the thorax, sufficient, indeed, to prevent locomotion, to any extent, on the part of their unfortunate possessor. In Huston's[14] case the right breast weighed twelve pounds, the left twenty pounds. Demarquay[15] removed a left mamma, after second pregnancy, weighing 8 kgm. (about 17½ lbs.). Skuhersky[16] records mammæ of eighteen pounds and nineteen pounds. Esterle,[17] in a case which came under his observation, judged the breasts, in the third month of pregnancy, to weigh from twenty-six to thirty pounds, confining the patient to bed. Chassaignac and Richelot report an instance of a breast which weighed thirty pounds, and hung down as low as the knee. Durston[18] made an autopsy of a girl whose right breast was supposed to weigh forty pounds, and whose left actually did weigh sixty-four pounds. The skin covering such enormous masses as these will, of course, be greatly stretched and somewhat yellowish in color, usually roughened also. A certain woman was married in 1853. After two pregnancies the left breast was so large that it reached to the umbilicus, and was removed in 1858. After removal it was found to weigh sixteen and a half pounds. The following statement in regard to it is from Schmidt's *Jahrbücher*, t. cvi., p. 51, 1860: About 2 litres of milk, very white, flowed from the tumor, showing here and there a streak of blood, without odor, alkaline, thick, resembling good cream; specific gravity, 0.98 to 0.99. A certain quantity, analyzed by Professor Schlossberger, showed: Water, 67.52; fat, 28.54; sugar and extractive matters, 0.75; casein, 2.75; salts, 0.41.

The tumor was examined microscopically, and from this examination it appeared that "the stroma was made up of fibrous connective tissue split roughly, the cells communicating with each other by numerous projections containing here and there fatty granulations. The small vesicles of the acini, pear-shaped, rounded, or elongated, . . . were slightly longer than normal, and enclosed, as did the commencing excretory canals, many small bodies having a well-defined outline, and containing shining nucleoli and a large number of fatty globules. The larger excretory canals presented the usual structure. The lumen walls were made up of compact fibrous connective tissue, mixed with cells, but without trace of glandular elements. Epithelial lining was lacking. The origin of these cavities was due very probably to a partial dilatation of the tissue by accumulation of its contents, which had brought about, on the one hand, destruction of gland substance, and on the other, a new formation of connective tissue." Demarquay's case, already referred to, showed on microscopic examination fibrous degeneration. There existed, in the extirpated breast, a central cavity containing a serous fluid in which were small oil globules, granular globules, and blood cells.

Cause.—Nothing certain is known as to the cause of this increased growth; menstrual irregularity or actual suppression has seemed to be the exciting cause. Increase with each succeeding pregnancy is noted. In Huston's case the ovaries were found diseased. If we consider how close are the relations between the different parts of any system in the human economy, it is fair to infer some general disturbance of the generative apparatus prior to the onset of mammary hypertrophy; but of what character such disturbance is, we are, for the present, in doubt.

Between the ages of fourteen and thirty the affection under consideration is most likely to occur. While it has been established that both breasts may become hypertrophied, the left seems to show a greater predisposition to such hypertrophy. An extremely interesting example of temporary[19] increase in bulk,—the erection of the mamma,—during a paroxysm of intermittent fever, is noted by Ferrus (*Gaz. des Hôp.*, 1846, No. 90, p. 358); it yielded to quinine. At the onset of the trouble the mammæ are large and firm; subsequently, however, they are pendulous, and thus appear pedunculated; the lobes are easily distinguished, the areola is large, sensibility is lessened, and perhaps there may be some œdema at the depending portion. The beginning of the disease is insidious, and its progress is characterized by alternations of rapid increase and apparent quiet; entire retrocession is not observed. Durston's[20] case followed a very rapid course, death closing the scene in three and a half months. After delivery, should hypertrophy commence during pregnancy, growth ceases. In Huston's case, gangrene followed a blow, death ensuing. MacSwiney[21] relates a case in which removal of one breast made the other grow faster.

The *prognosis* is not grave, except when the mammary increase is accompanied by general emaciation, with frequent pulse. Esterle[22] met with such a state of affairs, and found opium to give relief up to the time of confinement, when improvement took place. It is possible that the induction of a miscarriage would be necessary, other means failing, but this should be done only when the life of the mother is gravely imperilled.

The indications for *treatment* are both local and general. If menstruation be absent, induce it, if it be too profuse, diminish it; if it occur during lactation, arrest it; should arrest of lactation be the exciting cause, then re-establish the secretion—in other words, keep the generative apparatus normal. Iodine and iodide of potassium, to be administered internally and by friction, are indicated. Locally, support and compression by rubber bands will be found useful. Other means failing, removal of the ovaries, or the ovaries and tubes, might, by establishing the menopause, bring about a cure of the trouble under consideration. I am not aware that this last treatment has ever been adopted; it is, however, physiological and worthy of trial.

Other means failing to arrest growth, amputation is called for. Prior to removal of the breasts vascularity may be diminished by suspending the organs, as in elephantiasis of the scrotum. The use of Wyeth's pins is to be thought of also.

Diseases of the Nipple.—The nipple, save in lactation, rarely attracts notice; during the active life of the mamma, however, it is far otherwise. Its physiological perfection is a matter of extreme moment, not for the mother only, but for the health of the infant. A well-formed nipple of sufficient size, not buried deeply in the areola, but standing out from the skin surface, is to be secured before the end of pregnancy. Should this development not occur during the last months of gestation, gentle traction upon the nipple, with pressure backward on the areola, will be of use in aiding protrusion. Suction by means of an air pump has also been tried.

After the termination of labor, two causes are paramount in causing nipple disease: (1) Lack of development; (2) lack of cleanliness. The first offers an obstacle to the emptying of the breast, while the effort of the child to suckle excites the mamma to active secretion; as a result there will be retention and engorgement. The second, lack of cleanliness, conduces to an unhealthy condition, with a long catalogue of skin diseases, erosions, fissures, etc. Not only then is the protrusion of the nipple to be assisted in the manner described above, but the tender skin covering it and the areola should be hardened by frequent cool bathing during the eighth and ninth months of gestation, or perhaps by the employment of a slightly astringent lotion.

After the child nurses, the nipple and areola are to be gently and thoroughly cleansed, in order that the baby's saliva or a little milk, etc., may not rest in the natural rugæ of the part, and so induce irritation or a worse condition. Erythema and eczema present no symptoms not seen elsewhere; ecchymoses, from the child's suction and chewing while suckling, are recognized by the ordinary signs. Paget has described a chronic eczema which has its starting-point in the nipple; after destroying the latter, the disease gradually extends both over the surface and into the substance of the mamma, and finally terminates in carcinoma. Investigation seems to negative the simple character of this eczema, and it is known as malignant papillary dermatitis. The prominent characteristics are: a bright red raw surface, slightly raised, with a well-defined border; to the touch, a certain firmness or parchment induration; secretion scanty; existence very chronic. The areola and nipple are affected; the latter disappears. The disease is recognized as epithelioma histologically and requires similar treatment. Removal of the nipple only is useless; complete removal of the breast, as for other carcinomata, is called for.

Fissures, erosions, etc., when first established, are best treated by slightly astringent applications, afterward by emollient washes. Later, after the child has nursed, the breast may be washed, dried, and powdered with bismuth subnitrate, lycopodium, etc. I have seen excellent results follow the application of pure rubber dissolved in chloroform to the fissures, before the child is allowed to nurse. The application of a four-per-cent. solution of cocaine is reported as giving excellent results. Shields and artificial nipples of one kind or another may give good results, or the secretion of milk may require suppression in order to bring about healing. Abscess of the nipple is infrequent, and, according to Velpeau, occurs in a milk channel most often; under such conditions milk will escape after the discharge of matter. Rarely more than a drop or two of pus is formed.

Chancre of the nipple and areola is usually acquired by inoculation from a mucous patch, and resembles chancre of the lip. The amount of induration is very marked, not, however, appearing suddenly; parchment-like at first, the induration spreads to subjacent tissues, and may involve an area equal to that of a silver dollar. If the breast is being nursed, a scab is not allowed to form; otherwise a covering crust is not unusual. The primary lesion of syphilis may appear as an erosion, fissure, or ulceration. An axillary bubo will develop in connection with it, more often just under the edge of the great pectoral muscle than deep down in the axilla. The progress of the chancre is slow and painless, changing, with the advent of secondary accidents, into a mucous patch. During the early stage only of the disease will there be room for doubt; absence of pain, however, and the presence of a raw surface are to be looked upon with grave suspicion. In the event of a nursing woman being affected, the mouth of the infant she nurses is to be scrutinized closely.

Hyperæsthesia of the nipple, accompanying a rigid condition of the organ, has been noted, and will probably depend upon disturbed function of the uterus and appendages.

A similar hyperæsthesic condition of one or both breasts may be met with, and is likewise dependent upon an artificial mode of life, inducing defective menstruation.

Neuralgia of the Breast.—Neuralgia of the breast, the so-called irritable mamma, is to be classed with the two preceding affections, and is the outgrowth of incomplete or deranged sexual life. The subjects are usually unmarried, but not always; young, under twenty-five years, slender, with pale complexion, of lax muscular fibre, and not dependent on their own exertions for a livelihood. They will show strong predilection for trashy literature and laziness, rather than for the standard authors and exercise; the ism of the day will prove a subject of absorbing interest to them. Other hyperæsthesic spots or lines generally exist upon the skin of such individuals,—along the spine, for instance, or over the intercostal nerves,—and certain attitudes or motions will be complained of as liable to induce great suffering. Some sorrow may have been experienced, and the subject of it, from overmuch thought, gradually develops sympathy for herself, changes her mode of life, and generates a mammary pain. Physical examination of the breast shows no cause for suffering.

Treatment consists in regulating menstrual life and causing the patient to pursue an active and useful existence. In my hands, far more success has been thus attained than by resorting to, and relying largely upon, drugs. Menstruation, whether excessive or deficient, is to be rendered normal by appropriate means. An action of the bowels once daily is to be secured; the diet should be simple, nutritious, and not in excessive quantity; the clothing should be warm and loose, not confining natural movements; the function of the skin should be assisted by cold sponging; regular exercise should be insisted on; the patient should retire to bed early and rise early; dime novels should be put aside and the classics read, so that both mind and body may gradually be led to a normal healthy condition;—under which régime the mammary pain is likely soon to depart. Briefly, the treatment may be stated in the old saying, "Live on sixpence a day and earn it."

Contusions and Wounds.—Contusions of the mamma are of interest as having given rise to malignant disease in a certain number of cases. In order properly to estimate violence as a factor in the etiology of carcinoma or sarcoma, the number of bruised breasts not the seat of malignant growths should be known. This is manifestly impossible, and with our present knowledge we must remain in doubt concerning violence as a factor in the etiology of malignancy. Ecchymoses without traumatism have been observed in women menstruating with difficulty, blood also oozing from the nipple, perhaps.

Wounds of the mammary gland bleed freely; parenchymatous hemorrhage and much oozing follow. Pressure with sponges or cloths wrung out in hot water is the most efficient hæmostatic; healing is not rapid and pus formation is usual.

MASTITIS.—Inflammation of the breast may occur at any age, but is found far more often during the early days of a first lactation than at any other time. It is no uncommon circumstance for the mammæ at birth to be somewhat swollen and to give exit to a small amount of discharge more or less milky in character; if let alone, no harm follows. Injudicious handling on the nurse's part, to "work out the milk," is almost always indulged in with the result of causing an abscess somewhat often. Up to and including early puberty mastitis is rare, and when present is apt to be chronic rather than acute. The subjects are girls of feeble muscles, pasty complexion, torpid bowels, etc., and they present those symptoms which are generally grouped under the term strumous. Early opening of the abscess, general tonics, and out-of-door life, with regular hours, suffice for a cure. During pregnancy and the normal mammary development consequent thereon, abscess—save from traumatism—is very rare; but with labor the scene changes. The mammary inflammation and abscess which occur most frequently during the first month of lactation depend, in the great majority of cases, upon a defective development of, or morbid condition of, the nipple. The nipple is so small that tne child grasps it with difficulty, suckling is imperfect, and the mamma is not emptied; or a cracked and fissured nipple is so painful, when grasped by the baby's mouth, that suckling is again imperfect; or, from the inflamed nipple as a starting-point, trouble extends to a distance, through the lymphatics. The inflammation and abscess met with in early lactation are recognized as occurring, first, in the subcutaneous connective tissue outside the gland proper—subareolar; second, beneath the gland in relation with the thorax—submammary; third, in the connective tissue of the mamma—interlobular. To these three classical situations there should be added a fourth: in a lacteal sinus. The latter form of abscess, although not met with so soon after birth as the others, is worthy of recognition.

The cause of mammary abscess is not difficult to find. Pregnancy calls into life a hitherto comparatively rudimentary organ for the performance of an active function, and failure of any part of the organ determines an accident. The nipple, a healthy condition of which is essential to proper escape of the mammary secretion, is subject to violence, etc., from the infant, and an infection follows. Lack of cleanliness is the cause most frequently met with.

A subareolar abscess, not larger than a filbert, is found in the connective tissue of the locality indicated by the name, and is recognized by the usual signs. An early incision is indicated, in a direction radiating from the nipple to the periphery. I have never been able to appreciate the humanity of waiting until a mammary abscess "points"; great pain is thereby entailed upon the unfortunate woman, and the function of the breast is kept in abeyance, or perhaps permanently impaired. The many means for obtunding suffering now at the surgeon's command render procrastination most injudicious from a pain-saving point of view, if from no other.

Submammary abscess is rare; a collection of pus forms in the connective tissue which attaches the breast to the great pectoral muscle. Inflammatory fever is apt to run high, movement of the arm and chest muscles increases pain, and the whole breast is pushed forward, is tense, retains its contour and imparts to the examining hand a sensation as though the mamma rested upon an elastic cushion; fluctuation at the periphery of the breast may sometimes be felt late in the affection. Large veins will be seen wandering through the skin which covers the breast. This variety of abscess may be caused by an interlobular mastitis, by an axillary abscess, by a carious rib, or by the bursting of an empyema through the chest wall. An opening is best made, *in the absence of some special indication*, below and to the outer side. The incision should be of moderate length, and a director should be introduced into the wound as a guide for the dressing forceps, which should be withdrawn open in the usual manner. The use of a drainage tube is expedient, and, should free exit for inflammatory discharge not be afforded by one opening, then another should be provided. The breast should be well supported and pressed against the chest by a bandage or by strips of adhesive plaster. Should an empyema or carious rib exist, treatment proper for it is to be instituted. A carious rib will generally be tuberculous. Inflammation of the gland proper or of the interlobular tissue follows engorgement consequent upon a cracked or excoriated nipple, or, indeed, upon any cause preventing free discharge of milk. A sense of discomfort is soon followed by pain, etc., and fever is very marked. Occasionally a chill ushers in the disease. The interlobular tissue is first attacked, and the inflammation may extend between several lobes, or to the sublobular tissue. The strong capsule of the mamma opposes extension toward the skin, and pointing occurs late, pending which the glandular tissue may become involved and suppuration in it occur, permanently impairing the affected lobe or lobes. Fluctuation is not found early, and should not be awaited; acute pain somewhat localized, hardness, and elastic tension, will suffice for a diagnosis, and will justify a puncture, followed by incision if matter escape. In this form of abscess, as well as in others, a sensitive and enlarged gland may be met with in the axilla. Should artificial opening be deferred, the matter slowly approaches the surface and then points rather suddenly. Successive abscesses may form in the mamma, as the inflammation slowly extends from one place to another.

Successive formations of pus dépôts, following acute mastitis, are indications of a too limited opening, with incomplete discharge of matter. During acute inflammation a mamma should not be nursed by the infant, but lacteal engorgement must be carefully prevented by the diligent use of a breast pump; it is usually not necessary entirely to arrest milk formation by drugs, etc., unless a discharge of pus by the nipple is chronic or the abscess shows no disposition to heal. Acute inflammation of a lacteal sinus is infrequent, occurs usually long after the puerperal condition, is met with in anæmic patients, and follows interlobular mastitis, or more often, perhaps, obstruction of the outlet through the nipple. Probably a catarrhal inflammation of the mucous membrane is present. The prominent symptoms are: pain over the sinus, which increases with distention; discomfort on pressure usually; and, during quiescence of the gland, pressure will cause pus to exude from the nipple. The two instances in which I have recognized this condition were treated in various ways; the mammary secretion disagreed with the nurslings and it became necessary to arrest lactation in order to effect a cure.

It has been already said that the incision to evacuate pus from a mammary abscess should be made in the direction of a line drawn from the nipple toward the periphery of the gland.

Chronic abscess is sometimes, though rarely, met with, and is more apt to be confounded with scirrhous carcinoma than with any other morbid condition. It begins deeply in the gland, and incorporates surrounding parts by firm exudation; later, the nipple may be somewhat retracted, the skin dimpled, reddened, and adherent; also the axillary lymphatics may be enlarged and tender. Women whose health is poor and nutrition defective are usually affected. A local tuberculosis is to be suspected and the bacillus sought for. A diagnosis, differential, between chronic abscess and scirrhus is sometimes so difficult as to require an incision. The treatment is free incision, generous diet, and general tonic regimen. Port, beer, or porter will assist recovery by strengthening the patient. Tuberculosis of the mamma, with our present knowledge, would probably escape early recognition. A tumor slowly suppurating, leading to the formation of sinuses with undermined edges, in a subject of tuberculous tendencies, would excite suspicion which the microscope would be called upon to confirm, by disclosing the bacillus. Extirpation will be, of course, the proper treatment; sinuses should be "spooned" and iodoform applied. In a certain number of women a breast which has been the seat of abscess becomes the seat of malignant disease subsequently. I have not been able to see that the two conditions bore to each other the relation of cause and effect. For, while carcinoma is found in a breast which has been the seat of mastitis, yet many mammæ, which have been similarly affected, do not develop carcinoma. I have noted a carcinoma in one mamma which had always been healthy, the other breast having suffered from inflammation after confinement. It is natural to suppose that, if much induration remains permanently after mastitis, malignant disease would be more apt to develop in it than if no such induration were present.

MAMMARY TUMORS.—*Classification.*—With our present knowledge of mammary tumors, it may be safely said that any classification is but provisional, and will need modification from time to time, as additional facts are added to those already known. Tumors may be considered as indicating new formations and cysts, alone or in combination, and are best grouped according to their anatomical elements. It is unfortunately a fact that the clinical history of a growth cannot be stated so soon as the histology is known, but it can be done far more accurately now than was possible some time since, and more accuracy is daily being attained. I submit the following classification:

I. Cysts.

II. (*a*) Tumors resembling fully developed connective tissue: fibrous tissue, *fibroma;* adipose-tissue, *lipoma;* mucous tissue, *myxoma;* bone, *osteoma.*

(*b*) Tumors resembling embryonic connective tissue: *sarcoma.*

III. Tumors resembling epithelial (secreting) tissue: *carcinoma.*

IV. Tumors resembling the more complex higher tissues: gland tissue, *adenoma;* nerve tissue, *neuroma;* vascular tissue, *angioma;* the two latter so rare as to be disregarded.

Of the foregoing tumors, sarcoma and carcinoma are classed as malignant, the others as non-malignant or benign. Carefully kept clinical records, supplemented by accurate anatomical research, are greatly needed in the study of mammary growths, and the absence of such records renders much experience in the past quite useless at the present time. Probably no one word has brought about this result so much as the term "cancer," which is used either clinically, or anatomically, or as a means of concealing ignorance, by different observers. Clinically it means malignant, anatomically it means carcinoma; to avoid misunderstanding, the term will not be employed.

Cysts are sacs enclosing fluid more or less thick. A lacteal cyst—galactocele—is a tumor containing milk, normal perhaps, but more often having undergone changes during retention. A sinus or duct becomes closed, and is gradually dilated by milk as fast as it is secreted. The tumor begins, as a rule, beneath the areola, without inflammation and with little pain, and extends toward the periphery, usually in a nursing woman. Should the occluded duct be in a lobule, the tumor will commence deeply, and at a distance from the nipple. Increase at first is rapid; later, however, if lactation cease, diminution in bulk occurs, the cyst parting with its fluid and becoming more solid; its contents will then be curd-like, consisting of epithelium and fatty matters. Lacteal cysts of enormous size have been recorded; they are usually single, and do not involve the overlying skin unless inflammation supervene. When subcutaneous they are darker under direct illumination than is the adjacent skin. In a case observed by me, tension of the cyst varied with the active or passive state of the gland. Pain is very rare, and the patient complains only of the size of the breast. The general outline of the cyst is oval and smooth, more rarely lobulated. This latter shape is due to rupture of the wall at some point, and escape of contents which become encapsulated in connective tissue. The diagnosis offers difficulty only when, from long retention, the cyst-contents have become more or less solid; but even then the previous history enables the surgeon usually to avoid mistakes.

In a nursing woman, puncture or aspiration relieves temporarily, but does not cure, for the cyst refills quickly; injection with iodine tincture is equally inefficient. A free incision, followed by suppuration of the sac, or extirpation of the cyst, are the most reliable methods of cure; of the two, probably extirpation is the less painful. In a non-nursing woman aspiration, followed by injection of iodine tincture, offers more chance of cure, and should be tried, but the more radical measures mentioned above will probably have to be resorted to.

Non-lacteal cysts occur before and after the menopause, and result from the obstruction and subsequent dilatation of one or more ducts. Such cysts are usually multiple, not large, scattered through the gland, and contain a fluid more or less thick, secreted by the lining membrane of the dilated duct. This fluid may be clear or colored; and these colored cysts, in which the colors red and yellow predominate, are found more often in advancing years than at an earlier period (about puberty). In the nursing woman the cysts under consideration are rare: they are met with in sterile women, or in those who have long ceased to bear children and approach the menopause. Pain is exceptional, but weight and discomfort are complained of. Increase is slow and gradual; lymphatic implication is never seen. The diagnosis is made with difficulty; and, after all, that is a matter of small importance, since extirpation alone promises relief, if multiple cysts exist. Discharge from the nipple is a not infrequent accompaniment of cystic growths. Large single cysts are usually found near the centre of the mamma; multiple cysts, generally small, occur more often near the periphery. Both breasts are sometimes affected, but never to the same degree. Obstruction of a duct, causing the cyst, occurs in the old, probably from contraction of the fibrous stroma, while in youth defective evolution—excessive—of an acinus is invoked as a cause; hence the terms "involution cysts" and "evolution cysts," as they are called. The diagnosis rests on the slow growth, shape, consistence, and multiplicity, on the absence of glandular enlargement in the axilla, and, in case of puncture, on the escape of contents. When many cysts exist removal of the breast is the only procedure that will afford relief. In the case of a single cyst the sac may be opened, suppuration induced, and a cure by granulation obtained. Hydatid cysts of the breast are extremely rare, and, the growth being slow, this variety will usually be confounded with a retention cyst. On incision, daughter cysts may be seen, or hooklets may be found with the microscope. Healing by granulation, after discharge of the hydatid, is to be expected.

Cysts in relation with tumors will be found under the heading of the appropriate new growths.

Extravasation of blood, which may become encysted, has already been referred to. The ordinary wen—sebaceous cyst—occurs rarely in the breast, and attains but small size.

Tumors Resembling fully formed Connective Tissue—Fibroma, Lipoma, Myxoma, Enchondroma.—Of these the first named is much the most frequently met with; indeed, it is much the least rare of benign mammary growths. It is composed of hyperplastic connective tissue, together with glandular elements, more or less imperfect. It is this latter circumstance which has given rise to confusion, the terms adenoid, fibro-adenoma, adenocele, being used by various observers. The fibroma may enclose one or more cysts, from dilatation of contained ducts, or it may project into a duct which becomes dilated, thus appearing as an intracystic or intracanalicular tumor. More precise information will be found under the headings *Adenoma*, and *Tumors.*

Fibrous tumors are observed during the period of active menstrual life, preferably between the ages of sixteen and thirty, yet instances have been recorded as early as twelve and as late as fifty-six years. An overgrowth existing in an active organ would be expected to induce pain and impair function; and the first expectation is verified in many cases, for pain in the breast during menstruation and pregnancy is common; during menstruation and pregnancy, also, increase in size of the tumor may occur, to subside as the gland regains physiological rest. Hereditary predisposition is not apparent, and it is a singular fact that the negro, in whom fibroma uteri is very often found, is very rarely the subject of circumscribed fibroma mammæ. The variety of growth under consideration presents itself as a circumscribed, rounded mass, firm and elastic to the touch, with here and there, perhaps, a protruding boss, in which fluctuation may be apparent, indicating cystic association. The most usual site is that of the periphery of the breast, above the nipple, where the tumor will be found projecting under the skin; when deeply situated within the gland a fibroma is more apt to be intracanalicular. Variation in tension of a cyst, from absorption of its contents, will cause an apparent change of consistence in the tumor. A capsule is usually present, but where much glandular tissue is joined with the fibrous —*e.g.*, in intracanalicular growths,—the capsule is not complete. Neighboring tissues move freely over the growth. Section shows interlacing bundles of white fibrous tissue, with moist surface, and also, perhaps, acini or ducts dilated into cysts. While these fibroids usually occur singly, several may exist in one breast, or in both breasts simultaneously; they only exceptionally attain great size. The rate of growth is slow in solid tumors, but more rapid in the cystic variety; a sudden and very rapid increase is almost certainly an evidence of the cystic character of the tumor, and will cause change in its shape; cysts are more apt to occur (cysto-fibroma) toward the end rather than the beginning of menstrual life. A discharge of serous fluid from the nipple may occur with an intracanalicular growth; when the fluid is bloody, telangiectatic formation, or rapid growth (with increased vascularity), is probable. Adhesion of the growth to the skin, or surface ulceration, occurs as an accident only. The neighboring lymphatics are not involved, and though a recurrence may be, and is, observed in rare cases, yet such recurrence is as a local growth without tendency to infiltrate adjacent parts. Fibroma rarely undergoes degenerative change—fatty, myxomatous, and cystic changes being the most frequent. So far as regards danger to life, a favorable prognosis is indicated. The treatment proper for fibroma is removal by incision, so directed as to interfere as little as possible with mammary function.

Lipoma and *enchondroma* are not met with in the mamma, or so rarely as to be museum curiosities. Submammary lipoma has been seen, however, a certain number of times, and in no respect does it differ from fatty tumor elsewhere in the body, save perhaps that it has been more frequently observed in early life. The diagnosis and treatment are the same as in other parts of the body. Myxoma is rare, and presents itself in the breast as a single, rounded, perhaps bossed tumor, usually in the upper half of the breast. On section it appears as a light-colored, jelly-like mass, yielding apparently mucin—hence the name myxoma. Not infrequently fibrous, vascular, or fatty areas exist in the growth. The tumor originates in the connective tissue between the lobules and is usually encapsulated. The latter half of menstrual life is the chosen age. Inflammation occurs exceptionally, but may induce ulceration of skin already infiltrated or stretched, with, perhaps, protrusion of the growth, which is movable usually in the mammary tissue and also upon the thorax. Increase is more rapid than that of fibroma, and the consistence is less firm; a cyst, if present, will not be recognized very easily. Involvement of both breasts (simultaneously) is not seen. Retraction of the nipple is not observed, pain is wanting, and adjacent lymphatics are uninvolved. An incision will usually be required in order that the diagnosis may be made. Removal of the tumor by careful dissection will sometimes be followed by a recurrence *in situ*; removal of the entire gland, together with any involved skin, is therefore indicated.

The term malignant, applied to a morbid growth, is used to indicate a tumor differing histologically from the tissue in which it is situated, having a tendency after removal to recur *in situ*, and having also a tendency to reproduce itself in distant parts of the organism.

Sarcoma is a tumor composed of cellular elements of the connective-tissue type, which do not develop to maturity but remain embryonic; an intercellular substance is present, though but in scant quantity, and there is a new growth of vessels.

Sarcomata are named according to the character of the cells of which they are mainly composed: spindle-celled, round-celled, myeloid, lymphoid, etc. Not infrequently different parts of the same tumor show variations of cell growth, and with some this is the rule, *e.g.*, with myeloid tumors, in which the giant cells (myeloplaxes) rest in a spindle- and round-celled stroma (for histology see article on *Tumors*). Rarely seen before the establishment of menstruation, sarcoma invades the breast by preference between the ages of thirty and forty years, appearing infrequently after the cessation of menstrual life. In this respect it differs from carcinoma. Spindle-celled sarcoma is most often met with at an earlier age than other varieties. I am unable to connect the sterile or multiparous state with the etiology of sarcoma, although the relation with menstruation has been referred to. Traumatism is the unmistakable starting-point in certain cases; antecedent inflammation, save in very exceptional instances, is lacking.

Carcinoma, as I have noted, may develop from an induration left by puerperal mastitis; but I cannot recall ever having had such an experience with sarcoma. The upper half of the breast is more often affected.

In its general outlines sarcoma of the breast is rounded, oval, etc., in shape, and there exists a capsule which does not shut off the tumor from surrounding parts, so as to prevent extension; the capsule is formed of connective tissue pushed aside by the increasing tumor, and is infiltrated by its proliferating cells; outside of the capsule there are to be seen (microscopically), principally along the vessels, numerous cells, which I believe are already impressed with the character of the original tumor, or are direct offshoots from it, and develop into a similar neoplasm. The insufficiency of any operation which attemps to effect a cure without destroying such an area of infection is patent. The shape of the sarcoma varies with the rapidity of its growth, there being always a tendency to increase in the direction of least resistance. Sudden change in outline indicates a giving way of an opposing structure, cyst formation, or else extravasation of blood from a ruptured vessel; a general rounded outline will be preserved, however. Trauma may give rise to extravasation of blood and consequent change of shape, but here the history aids the diagnosis. The growth of sarcoma varies much, and bears a certain relation to its anatomy, the spindle-celled variety being of slowest growth and firmest consistence, and having a more perfectly defined capsule; while, on the other hand, a round-celled sarcoma is softer, grows rapidly, presents often rounded outcroppings, and the new-formed vascular channels are apt to rupture and permit extravasation, not in one only but in several places. Cystic formation may cause sudden change of shape. Variation in rate of increase characterizes sarcoma; a nodule may remain for years without exciting suspicion, and then, from no known cause, grow with extreme rapidity. It is not usual for rapid growth to be succeeded by slow increase, but nevertheless this has been observed. When cystic or other degeneration occurs, slow growth is not to be expected, but rather continuous progress; and the same is to be said when extravasation occurs, save from trauma. An intercurrent inflammation is apt to induce quick growth.

Increased temperature is noted in rapidly growing sarcomata. The volume sometimes attained is enormous, tumors of many pounds in weight being recorded.

Sarcoma is usually single, and very rarely affects both breasts simultaneously.

Adhesion to the chest wall is not usual, even if the tumor be of extreme size; on the other hand, implication of the great pectoral muscle is seen, but not so frequently as in the case of carcinoma. Protrusion through an intercostal space into the thorax has been observed.

Implication of the chest muscles will be recognized by investigating the mobility of the tumor when the great pectoral is alternately rendered tense and relaxed. The skin, although greatly stretched, generally remains movable over the neoplasm for a long time, and may be discolored red or purplish. Ulceration of the skin from pressure of, and incorporation with, a subjacent growth is much less often seen than in the case of a carcinoma. When, however, the skin has given way, fungous protrusion is usual; the nipple is not affected, and a serous or somewhat blood-stained oozing, which has been observed in many cases, indicates involvement of ducts in or by the morbid growth; hence it occurs with cysts.

Pain is often complained of; not, however, in my experience, until the tumor had attained a certain size. When ulceration is present, a certain discomfort is to be expected. I am inclined to attribute the occurrence of pain to pressure and traction upon nerves, rather than to the fact of their being involved in a rapidly growing tumor. Pain is referred to the arm in certain cases.

Lymphatic enlargement is rare in sarcoma, and, when present, is due to irritative rather than to specific implication of the glands. Axillary bubo is therefore not often seen, and, if present, would raise a suspicion of carcinoma. The presence of ulceration, either from implication of skin in the morbid growth or from irritating applications, is often followed by hyperplasia of the adjacent lymphatic glands.

It is believed that sarcoma becomes generalized by way of the blood-vessels rather than by that of the lymphatics; hence the apparent immunity of the axilla in advanced disease.

General infection (sarcomatosis) is recognized by the formation of metastatic tumors. The lungs, presenting the first set of capillaries which sarcoma elements would meet after entering the circulation, would be expected frequently to be the seat of secondary growths, and such is indeed the fact. It is not possible to say at what time secondary tumors are most likely to appear, but it is always wise to question the lungs before operating upon a sarcomatous breast, lest a pulmonary metastasis be present, and the operation do harm by reducing the patient's strength. Local recurrence after operation is frequent, and while it is not possible to state the percentage in which a return *in situ* is to be looked for, yet it can be accepted as the result of clinical observation that the softer and more rapidly growing a sarcoma is, the more likelihood exists of recurrence; conversely, the firmer and more slow-growing the tumor is, the less chance is there of a return. Youth is more disposed to recurrence than age.

From the foregoing, one would expect a round-celled sarcoma to justify a more unfavorable prognosis than a spindle-celled one.

Cystic formations are present in many sarcomata; they result either from dilatation of ducts or from fatty or mucoid degeneration. Calcareous, bony, or cartilaginous formations have been noted, and are to be regarded as curiosities.

The only *treatment* that offers any prospect of a cure is extirpation, free and complete, so as to remove not only the tumor, but the area of infection, already referred to, as well. Failure to succeed in this latter condemns a patient to early recurrence *in situ*. Local recurrent tumors also are to be excised, and immunity from return is thus gained. The removal of one tumor, when the disease is generalized, is useless. The well-known case of S. D. Gross may be recalled with advantage:—A single woman was subjected to twenty-two operations in four years; the number of recurrent tumors removed was fifty-one, and varied in size from an almond to a hen's egg. Large portions of the pectoral, and also of the external and internal intercostal muscles, were cut away. Ten years and nine months after the last operation she was in perfect health.

Melanotic sarcoma is very malignant.

Carcinoma is an atypical new formation of epithelioid elements; for the anatomy, the reader will consult the articles on *Carcinoma*, and *Tumors*.

Carcinoma is the most common and at the same time the most fatal of breast tumors; it affects all classes and all social conditions. Scirrhus and encephaloid, usually known as hard and soft cancer, are the varieties most often met with, the former in far greater proportion than the latter, however. Forty-eight to forty-nine years is generally accepted as the average age of patients coming under treatment; but it is to be remembered that the tumor will have existed for a certain time already before being seen by a physician, or, what is occasionally met with, but I am glad to say rarely, a patient will have been advised by a physician to pay no attention to the lump, and so a long time may be passed in fancied security. My personal experience leads me to consider forty-eight years too late an average age when carcinoma is first observed, forty-five or forty-six being more exact. The menopause is the period just before or just after which carcinoma may be expected to appear; indeed, the period of two years preceding the cessation of menstruation is especially favorable for its development. The earliest age at which I have seen a scirrhous carcinoma of the breast is twenty-seven years. Before thirty-five the occurrence of carcinoma is very rare. Traumatism and preceding inflammation are occasionally exciting causes, but not sufficiently often to be considered as exercising a potent influence for evil.

Heredity has long been held up as having causative power, but such predisposition can at most be traced to nine or ten per cent. Occasionally the opposite is seen, as in the case of Mme. Z—— and family,[26] in whom sixteen deaths from cancer occurred in seventy years.

While, then, blows, the remains of a previous abscess, and hereditary peculiarity may and do exist in a causative relation with carcinoma, yet the degenerative changes in the mamma consequent upon cessation of function is, without doubt, the most powerful influence in the development of carcinoma. Carcinoma begins in one breast; its presence in both should be accepted as indicative of general infection; it is never encapsulated, but is infiltrated into the adjacent structures. Thus, the outline is not so well defined as in sarcoma, and while outcroppings are rounded, the body of the tumor may be in shape irregular; this is especially the case with scirrhus. Soft carcinoma is of rapid growth as compared with the hard variety; it is more vascular, more rounded in form, and gives to the hand a sense of fluctuation; the mammary gland is incorporated with, and not distinguishable from, the neoplasm. Scirrhous carcinoma, on the other hand, is of slower growth, of extremely hard consistence without much elasticity, presents to the examining hand firm but not large irregularities, and is apt to be flattened, as indeed the mamma is flattened; in a late stage only is it to be seen as a projecting tuber elevating the skin. Scirrhus conveys to the hand a sense of weight rather than of bulk. Soft carcinoma may attain great size. As a point of differential diagnosis it is to be noted that scirrhus commences generally within the mamma, which is felt, in an early stage, to surround it on all sides, except toward the thorax, of course. Adhesion to chest-wall contraindicates an operation, the rule in this respect differing from that for sarcoma, which may sometimes be removed with advantage under such circumstances, if of slow growth. Fixation to skin, as well as to chest, is marked in the scirrhus variety, showing itself by lessened mobility and later by the formation of dimples.

Adhesion to chest is recognized by lessened mobility, and is always preceded by the tumor becoming incorporated with the great pectoral muscle; axillary swelling will also be found at this time if sought for. Retraction of the nipple is an almost constant symptom in scirrhus, and results from incorporation of the large ducts with the tumor. Soft carcinoma and sarcoma do not present this peculiarity; hence its importance from a diagnostic view. A discharge from the nipple would indicate implication of the ducts; it is a rare symptom and has no clinical significance. In adeno-carcinoma a serous discharge from the nipple is common. From the preceding it would be expected that a certain fixation of the nipple, the impossibility of drawing it forward, would be present before retraction took place; this is so, and constitutes a valuable diagnostic sign early in the life of carcinoma (scirrhus). Besides adhesion and dimpling, infection of the skin may be recognized by the appearance of small, firm infiltrations, without elevation of surface or discoloration, in the neighborhood of the original growth. These indurations, which are first recognized by the touch, become harder, elevated, discolored, livid, and then ulcerate; in atrophic carcinoma they may even cicatrize. Their presence is indicative of an extremely large infected territory around the primary growth.

I have never seen good results follow operations upon such growths; the resulting wound does not cicatrize, and the skin edges rapidly become infiltrated with new growth. Much importance has been attributed to the presence of large veins in the skin of a breast as indicating a certain kind of tumor; I cannot admit that this is quite the fact, except in the general way that it is usual to find large vascular channels in the vicinity of a rapidly growing neoplasm. In atrophic carcinoma enlarged veins are very rarely seen, for here the circulation near the surface is not greatly increased. Ulceration in the skin is seen, commencing as a crack or fissure, which widens out and deepens, presenting the appearance of a shallow excavation with indurated edges and base usually ragged, of pale color; the discharge is thin and ill-smelling; partial healing, with a thin, unhealthy scar, sometimes takes place. When softening of the tumor occurs, from one cause or another, and the skin gives way, there results a deep, crater-like pit, with everted edges, hard, irregular base, and profuse discharge. Hard carcinoma pursues the manner of ulcerating first described, soft carcinoma the latter. Fungous protrusion I have not seen follow carcinoma ulceration. As has been said already it is seen in the ulceration of sarcoma.

Pain is variable. I have repeatedly seen carcinoma of the breast, with implication of the skin and several glandular enlargements in the axilla, and yet the patient only accidentally discovered that the mamma was involved in any morbid process. Two such cases have come under my notice within the past month: both patients were seen within four days after the discovery of the mammary swellings. The classical, lancinating, darting, shooting pains are exceptional in the incipient stage of the tumor; later, however, they are present; with inflammation and sloughing the pain is great; in atrophic scirrhus, with ulceration long continued, pain is extremely varied. Infection of adjacent lymphatic glands in carcinoma is a question of time; sooner or later it will occur, save in rare instances. The axillary glands, substernal, intercostal, and supraclavicular, sooner or later become involved. Just how soon glandular infection occurs is not known, as the primary growth exists some time before being discovered.

The axillary enlargements result from the passage of elements from the original tumor through the lymphatics, and their arrest and growth in the lymph glands, thus reproducing the disease in the armpit, from which, continuing their journey by lymph channels, tumor elements enter the general circulation, and carcinosis results. It will sometimes, though very rarely, be found that general infection occurs without glandular implication to any degree; this is to be explained by direct transmission through veins. Occasionally also slight glandular enlargement will disappear after removal of the original growth; in such a case it is clear that the glands were not carcinomatous, and were probably only irritated; but why this should occur in one case and not in another, we do not yet know. Carcinoma shows a predilection for the liver, lungs, and serous surfaces when it attacks internal organs. Colloid and cystic degenerations are those most often met with in carcinoma. Inflammation running into abscess is rarely seen except in connection with rapid growth, when also acute sloughing may occur.

The prognosis of carcinoma is extremely grave, if left alone or if operated upon. S. W. Gross[27] gives the average duration of life for patients not operated upon as 27.1 months, and for those who died after they had submitted to an operation, as thirty-nine months; which shows that the operation added a year of life to each patient. He furthermore computes the percentages of recovery at 9.05. Owing to the fact that operation for removal of carcinoma is now extended so as to remove adjacent structures which may be involved in the growth the percentage of recovery has increased enormously; probably twenty-seven per cent. of patients operated upon for carcinoma mammæ are now free from recurrence for three years after operation.

Carcinoma following long-continued ulceration of the nipple—Paget's disease—has already been referred to.

Within the past few years our knowledge of adenoma has undergone a great change. Instead of being often met with it is now believed to be one of the growths most rarely encountered, and the so-called adenoid growths, adenocele, and adeno-cystic tumors are recognized as composed of connective tissue, containing deformed glandular elements—fibromata.

It is doubtful whether it would be possible to differentiate clinically between fibroma and adenoma, nor indeed does it appear to be necessary, since both belong to the category of benign growths, and are to be subjected to like treatment. Perhaps the most notable fact observed in connection with adenoma is the extreme frequency with which cysts occur in its substance, a circumstance which is due of course to the presence of ducts which have undergone dilatation.

Transformation or change in a tumor is met with and is always to be regarded with suspicion if characterized by rapid growth.

Treatment.—A benign tumor of the breast is removed by freely uncovering it; the incision is to be directed from the nipple outward so as to do as little harm as possible to adjacent ducts, after which the growth is to be freed from attachment. It has been suggested that, to avoid a scar, the following manner of operating be adopted: "Carry an incision as long as necessary around the lower edge of the breast where it joins the thorax, raise the breast, and through the incision indicated remove the growth from the posterior aspect of the gland, arrest hemorrhage, insert a glass drainage tube, replace the breast," etc. Lateral stitches can be inserted before replacing the breast so as to give prominence to the breast. It is probable that few tumors require such an operative measure; benign growths are usually situated in the upper half of the breast, not beneath it, so that an incision through the skin, and at once down upon the tumor, is more simple. As the mamma is generally covered save in exceptional instances, the presence of a scar may be disregarded.

When malignant disease of the breast is presented for treatment it becomes necessary for the surgeon to decide whether an operation is expedient at all or whether the disease has spread so extensively as to preclude the possibility of benefit by operative measures. While it is impossible to lay down hard-and-fast rules, it may be said generally that operation is not expedient if the growth cannot be removed; if life is to be shortened by the operation; if pain and suffering are not to be diminished by the operation. The operation is to be undertaken if there is a good prospect of removing the growth; if life is to be prolonged; if pain and suffering are to be diminished. These questions the surgeon must decide, after which the operation itself must be considered.

It has been before said that outside and around a malignant tumor there is an area of tissue already sown with seed which, if not removed, will reproduce the original growth. Any operation which removes the tumor and leaves this infected area will certainly be followed by speedy recurrence; free and complete extirpation is therefore the first duty of the surgeon. In carcinoma, and perhaps sometimes in sarcoma, the lymph glands are involved; they are to be taken away. If they are enlarged and cannot be removed, no operation on the breast is to be undertaken. The glands above the clavicle, under the edge of the sternum, and along the ribs are to be searched for and removed. These two latter groups are more apt to be involved if the growth lies to the sternal side of the nipple. Not only the lymph glands but the lymph channels should be taken away with the breast, and these channels are in close relation with the pectoral muscles and axillary fat; so that extirpation of a carcinomatous breast or a sarcomatous one calls for removal of the tumor itself together with the entire mamma and skin over it which is or may be infected, both pectoral muscles, and axillary contents, consisting of fat, fascia, and lymphatics. It will be best, save in rare cases, to carry an incision into the neck, exposing the supraclavicular space, and to remove any lymphatics there found. It is difficult to state the lines of incision which shall enable the operator in all cases to carry out the above requirements. A tumor involving the skin near the sternum, and one involving the skin near the axilla, will call for different incisions.

Speaking generally, then: the breast is to be removed by an incision circumscribing widely the skin over the centre of the growth and passing through healthy tissue. This incision is to be extended into the axilla and down the arm, and will be more or less racquet-shaped, the handle passing through the axilla, and the other end, more or less round, corresponding to the mamma. From this incision a cut is to be carried upward over the clavicle into the neck. To facilitate closure of this extensive wound I divide the skin downward several inches along the anterior axillary line. The flaps so marked out, consisting of skin and connective tissue, are very freely reflected, the incisions are then deepened, and the great pectoral muscle on which rests the mamma is reflected from the thorax and clavicle. The lesser pectoral may be separated with the greater or be taken away during the dissection of the axilla. The axilla is now carefully cleaned by dissection of all fat and lymphatics, during which the lesser pectoral if present is removed. The supraclavicular region, edge of sternum, and intercostal spaces are searched for lymphatics, which are removed. It may be expedient to take away a piece of rib if suspiciously near the neoplasm. Dissection is facilitated by removal of breast and axillary tissue in one piece. Bleeding during the operation is controlled by hæmostats or ligature. As a marked furrow in the muscle distinguishes the portion of the great pectoral which is attached to the sternum from that which is attached to the clavicle, separation of fibres is quickly and easily made, and the clavicular portion rarely if ever requires removal. When left it assists motion of the humerus. So far as my experience goes, splitting the great pectoral tendon and dividing the portion that corresponds to the removed muscle can be accomplished most easily with scissors.

Closure of the large wound resulting from this operation may be effected by skin grafting or by forming flaps as occasion seems to justify; or else healing by granulation may be permitted. Mixter fashions a large flap from the other side of the sternum, and causes the unaffected mamma to slide until it lies near the middle line.

When dissecting an axilla I at once uncover the axillary vein at its lower (brachial) end, and with this as my landmark the affair becomes simple.

Occasionally ligation of the axillary veins is required: I have never seen trouble follow this procedure.

I have observed that patients whose wounds do badly, from erysipelas or other cause, suffer speedy recurrence; an additional reason for securing early cicatrization. Recovery from amputation of the breast is usually rapid, and the mortality is small.

Recurrence after amputation demands extirpation as in the first instance, unless the secondary growth occur at a spot where complete removal is not possible. By repeated operations I have prolonged life and given comfort for years. Several years ago I operated upon a single woman, aged forty-eight, for the third time, removing a small nodule as large as a pea, one-fourth inch in diameter, and also two indurated axillary glands. She was first operated upon in 1878, and for the two recurrences in 1882 and 1885 respectively. Microscopical examination enabled me to make a positive diagnosis in regard to its carcinomatous nature. An operation should not be undertaken if the primary growth cannot be removed together with involved axillary glands, or when it is apparent that general infection has already taken place. The surgeon, therefore, must not only examine the apparently affected region, but also investigate the integrity of internal organs as well. Extirpation of mammary growths by means other than the knife, *e.g.*, by caustics, scarcely requires mention; so much the best instrument is a knife, if properly guided. Until we can find a caustic which will seek out and destroy the neoplasm, sparing healthy tissue, the knife will hold the first place. It may perhaps be expedient, when the tissue is very vascular, or when the ribs are suspiciously near the base of a carcinoma, to apply a caustic after the knife has been used, but such instances are exceptions. When an operation is inexpedient, the surgeon must direct his efforts to the relief of the local discomfort by proper dressings, and to the amelioration of the general condition by appropriate medication. The condition of the patient is most unhappy, and I have always thought it expedient to allow opium or its alkaloid, morphine, in sufficient quantity to bring about a state of comparative relief. I have observed that in stout people recurrence of an extirpated growth is more rapid than in those of more slender build.

L. McLane Tiffany.

[1] Journ. Anat. and Phys., July, 1879.
[2] Thèse de Paris, 1877.
[3] Virginia Med. Month., vol. i., p. 87, 1874.
[4] Dict. des sc. méd., vol. iv., 1813.
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[6] Idem.
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[8] Jour. gén. de méd., p. 57, 1827.
[9] Jour. Anat. and Phys., November, 1872.
[10] Thèse de Paris, 1880, p. 63.
[11] Lancet, 1840, vol. ii., p. 637.
[12] Lancet, 1837, vol. i., p. 356.
[13] Wien. med. Presse, 1883.
[14] Am. Journ. Med. Sc., 1834, xiv., p. 374.
[15] Gaz. méd. de Paris, 1859, p. 818.
[16] Weit. neu. Beit. zur Chirur., 1841, pp. 42 64.
[17] Annali Univ. di Med., 1857, t. clxii., p. 53.
[18] Bibliot. de Manget, t. iii., liv. ii., p. 252 (from Labarraque, Thèse de Paris, 1875).
[19] *Loc. cit.*
[20] *Loc. cit.*
[21] Dub. Quart. J. Med. Sc., 1870, p. 349.
[22] *Loc. cit.*
[23] Brit. Med. Journ., 1874, 11, 106.
[24] Joly: Thèse de Paris, 1851.
[25] Trans. Edinb. Obst. Soc., 1875, 111, 122.
[26] Broca: Traité des tumeurs, vol. i., p. 152.
[27] Tumors of the Mammary Gland, p. 164.

BREATH,—air respired (E.) A. S. brǽð, breath, odor. Perhaps allied to Latin *fragrare*, to emit a scent: *fragum*, a strawberry; but this is uncertain.* Thus in the very origin of the word there is inherent the idea of odor. The breath consists of nitrogen and oxygen, the proportion of the latter being less than that present in the atmosphere; a little more than four per cent. of carbonic acid, aqueous vapor, ammonia, and organic impurities. Within the last quarter of a century, much work has been done in investigating the nature of the organic matter of expired air. Ben, in 1893, obtained 100 c.c. of water from 3,000 litres of expired air. The odor of this water was peculiar but not disagreeable. Its organic contents weighed 5 mgm. There were no alkaloids in it, but it gave a reaction for ammonia. It would seem that this organic matter is not capable of producing acute intoxication, but the untoward effects incident to breathing in limited spaces are due to lack of oxygen. There is no certain knowledge as to whether micro-organisms may be eliminated by the breath, although the laity believe in this possibility. Welch states that the consensus of authority is against the probability of such an occurrence. Experiments have shown the difficulty with which micro-organisms are detached from moist surfaces by air currents, so that it is likely that they are never conveyed to the outside air by ordinary quiet breathing. The proportion of carbonic acid is increased in the early stages of smallpox, measles, and scarlatina, and during the existence of any extensive skin disease. It is diminished in typhus fever. The temperature varies somewhat, being influenced slightly by that of the external air, but seldom falls below 90° F. When the temperature of the inspired air is very high, as in the hot room of a Turkish bath, the breath may appear, by comparison, to be cool. In fevers its heat is increased, but in the algid stage of cholera it is almost cold

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* Skeats' Etymological Dictionary of the English Language.

There is a deplorable lack of knowledge concerning the physiological odors of the breath In health the breath is nearly odorless, but there is a sweet odor from certain glands about the cutaneous limit around the nostrils. Nature has designed this as a sexual excitor, and together with other attractions between the sexes it helps to insure reproduction of the species. This is not characteristic alone of the female, but the male also, if living a comparatively normal life, possesses the same attraction. The pleasure of kissing is due chiefly to this source. Consequently, in blunted olfactories, osculation loses its greatest charm. Each person is characterized by his own peculiar nasal odor, and the more refined he is, and the higher in the scale of civilization, the more delicate the odor. On the contrary, the coarser the individual, the more heavy the odor, *e.g.*, negroes emit a musky odor. Individuals who are not in good condition for reproduction, or who are lacking in passion, possess slight nasal odors. It has been stated to be absent or disagreeable in pregnant women

Among the curiosities of literature, there are reported cases of luminous or bright red breath; and others of inflammable breath—in which there was a flash of flame from holding a lighted match near the mouth. This last phenomenon is probably due to the formation of combustible carburetted hydrogen from the chemical decomposition of breath James Gray, in the *Lancet*, speaks of the "peculiar odor of the breath previous to death," and cites two cases in which was exhaled the same phosphoric odor just before death

The term *halitosis*, diseased breath, is derived from the Latin *halitus*, breath, and the Greek, νόσος, disease (Howard). Offensive breath does not express a morbid entity. It is merely a symptom, however extreme it may be,—a functional disorder which may occur at any time of life. It is most common in the male; it may be due to various causes, never produces pain, is present under many different circumstances, is never dangerous, but it is sometimes the most striking and annoying feature of a case, and is so disgusting and humiliating that it causes misery not only to the patient, but to all within his environment. Very slight causes often modify the delicate breath of health, and in certain morbid conditions the odor is quite characteristic, and may be valuable as a diagnostic sign

The odor of the breath is modified temporarily by many causes. Mental emotion often exerts a powerful influence over the odor of the breath. If the many well-known pathological effects of excessive emotion be reviewed, this fact will not seem strange. For mental disturbance may so change the secretions of the alimentary tract and the glandular system that the normal elimination of waste products is prevented, and an extra burden is thrown on the lungs, with resulting foul breath. Or the sudden excitement may cause a greater destruction of tissue than normal, so that before the intestinal glands can accommodate themselves to this increase the burden of vicarious elimination is thrown on to the lungs. The subjects are, as a rule, conscious of its presence There is generally a pasty taste in the mouth, and this together with the disagreeable breath may be almost instantaneous with the occurrence of the emotion. Such patients are commonly neurotic and high-strung, and possess a mercurial temperament. Many volatile substances taken into the system through the ordinary channels are excreted in part through the lungs, and impart their odor to the breath. Thus turpentine, alcohol, onions, cheese, spices, and many other alimentary and medicinal substances taken into the stomach are quickly detected by their peculiar smell in the expired air. In women the expired air frequently acquires a disagreeable character during the menstrual period, said to be due to the nasal and retro-nasal secretion of the mucous membrane, which at that time is congested. In feverish conditions the breath acquires a sweetish, or sometimes sickening, character. This is particularly noticeable in children, and in them is often suggestive of the odor of chloroform. In diabetes mellitus there is often a peculiar sweetish odor, which is difficult to describe, and which has been likened to that of honey, sweet apples, or hay. In uræmia the breath is said often to acquire a strongly ammoniacal odor due to the non-elimination of the urea, which persists in the blood and combines with the water to form carbonate of ammonia. The skin also exhales the same odor. In pyæmia also the breath is peculiar and characteristic. Dr. Tavignot, a French writer, described, some years ago, a peculiarity of the breath in glaucoma, to which he gave the name of *haleine safranée;* and he maintained that this was constantly present in persons suffering from that affection. There are cases recorded of extensive burns in which the breath, formerly sweet, has assumed the disgusting odor of bisulphate of carbon. Migraine is often accompanied by a bad breath. Tuberculosis can often be detected by a characteristic breath. Pernicious anæmia, pseudo-leukæmia, and interstitial nephritis frequently have this symptom.

Various mineral substances, which are themselves nearly or quite without smell, cause, when introduced into the system in sufficient quantities and during a certain period of time, a very disagreeable odor of the breath. This occurs from stomatitis in some cases, and in others from the disturbance of digestion, induced by the chronic poisoning. The substances which most frequently are concerned in the production of toxic halitosis are, antimony, arsenic, lead, mercury, phosphorus, and sulphur. Sulphur imparts a distinct odor not only to the breath, but also to the perspiration after two hours.

In chronic alcoholism the odor of the expired air is very foul, not necessarily alcoholic unless liquor has been recently taken, but possessing a peculiarity all its own, and unlike anything else. The excessive use of tobacco not infrequently imparts a foul odor to the breath.

A permanent foulness of the breath is due either to interference with the elimination of the products of decomposition by the intestines and kidneys or to local causes existing in some part of the respiratory tract.

Perhaps the most frequent cause of a bad breath is dyspepsia, either gastric or intestinal. The hurry, excitement, and worry characteristic of our present century are greatly to blame for these ills. Overwork, excessive application to business, sedentary habits, and the habit of "bolting" food, all bring in their train irremediable results. In this case the elimination of the products of decomposition and of the effete matters of the tissues by the normal channels is interfered with to a greater or less extent, and the task of their excretion from the economy is in part thrown upon the lungs. The expired air contains a large amount of organic matter, which is often very ill-smelling and offensive. In cancer of the stomach or liver, disordered digestion is often heralded by a foul breath. In chronic constipation, especially, the odor of decomposing organic matter is most marked. The most common causes of constipation are a decrease in the secretion of mucus from the glands in the intestinal walls, or deficient peristalsis of the musculature of the same. Hepatic disorders always entail certain disturbances of digestion. A very common symptom of intestinal worms, especially ascarides in children, is foul breath.

Among local causes there are various affections of the mouth, nose, pharynx, larynx, and lungs.

Dental caries is a well-known cause of foul breath. This arises not only in consequence of the decay of the teeth, but also, and chiefly, from decomposition of food lodged in the cavities and between the teeth; also from tartar and the micro-organism leptothrix buccalis. These causes may give occasion to a fetid breath in persons who are careless in cleansing the mouth, even when the teeth are perfectly sound. Gingivitis, from arsenical or mercurial poisoning, or from scurvy, may give rise to a bad breath, as may also syphilitic ulcerations of the buccal cavity or fauces. Pyorrhœa alveolaris is also another cause. "Spontaneous stomatitis" occurs without any apparent cause. The entire interior of the mouth is affected, and the fetid saliva taints the breath. In many points this affection resembles mercurial stomatitis. Follicular stomatitis occurs at any age. This inflammation takes its origin in the follicles of the mucosa, on the in side of the lips, and on the sides of the tongue. In certain cases a vesicular eruption (herpes) is the first manifestation of the disease. There is a condition known as catarrh of the tongue, which is usually associated with dyspepsia, but may occur independently of it. Here again decomposition of mucus, epithelial scales, and food particles as well as bacteria are the offending cause. In necrosis of the jaw which may result from mineral poisons, decayed teeth, or syphilis, the odor is frequently sickening. The breath of patients suffering with carcinoma of the tongue and neighboring parts is very penetrating, but that from cancrum oris, stomacace, or noma, is almost unbearable, and once experienced can never be forgotten.

In nasal polypi, after the secretion from the nose becomes muco-purulent, the breath is apt to be disagreeable. Ozæna, from whatever cause produced, is frequently responsible for a most foul and repulsive odor. This is due, according to Browne, to the fact that "the crusts and discharges usually contain decomposing fatty globules and micro-organisms." Mouth-breathers with nasal stenosis are often afflicted with bad breath.

Like the odor of necrosis of the jaw, that of follicular tonsillitis and pharyngitis is sickening. In the latter case the odor is due to decomposition of the secretion and food particles filling up the follicles, and is often suggestive of fæcal matters. This inspissated secretion becomes cheesy in consistency. Chronic enlargement of the tonsils is apt to occur in young people with the so called scrofulous diathesis. The breath in these cases is often foul. In diphtheria there may be a disagreeable fœtor of the expired air suggestive of putrefaction. This is especially true of epidemic diphtheria. Putrid sore throat shares with diphtheria this symptom of halitosis. Syphilitic and tuberculous ulcerations in the larynx often impart an unpleasant odor to the breath, and the fœtor of some forms of bronchitis, of bronchiectasis, and of abscess and gangrene of the lungs is too well known to require any description.

Finally, some individuals suffer from a more or less fetid breath, the cause of which it is impossible to discover. It is often congenital; it is constant, and not dependent upon any apparent deviation from health, but is often associated with a strong and unpleasant odor of the sweat and other secretions.

In the following table the various conditions leading to the production of a bad breath are arranged under their several classes for convenience of reference

Causes of Halitosis.

Transient	Mental disturbance.	
	Various ingesta, medicinal and alimentary.	
	The menstrual period.	
Systemic	Fevers.	
	Diabetes mellitus.	
	Uræmia.	
	Pyæmia.	
	Glaucoma (?).	
	Burns.	
	Migraine.	
	Tuberculosis.	
	Pernicious anæmia.	
	Pseudoleukæmia.	
	Interstitial nephritis.	
Toxic	Antimony.	
	Arsenic.	
	Lead.	
	Mercury.	
	Phosphorus.	
Toxic	Sulphur.	
	Alcohol.	
	Tobacco.	
Digestive	Gastritis.	
	Dyspepsia.	
	Cancer of stomach or liver.	
	Constipation.	
	Hepatic disorders.	
	Enteritis.	
	Intestinal worms, particularly ascarides in children.	
Buccal	Dental caries.	
	Gingivitis.	Toxic.
		Scorbutic.
		Syphilitic.
	Stomatitis.	"Spontaneous."
		Follicular.
	Pyorrhœa alveolaris.	
	Lingual catarrh.	
	Necrosis of jaw.	
	Carcinoma of tongue and other parts.	
	Cancrum oris.	
	Lack of cleanliness.	
Nasal	Polypi.	
	Ozæna.	Herpetic.
		Syphilitic.
		From foreign bodies.
		Scrofulous.
		Idiopathic.
		Osteo-necrotic.
Faucial	Follicular tonsillitis.	
	Follicular pharyngitis.	
	Syphilitic ulceration.	
	Diphtheria.	
	Putrid sore throat.	
Laryngeal	Carcinoma.	
	Ulceration.	Syphilitic.
		Tuberculous.
Pulmonary	Bronchiectasis.	
	Putrid bronchitis.	
	Tuberculous ulceration (cavities).	
	Gangrene.	
	Abscess.	
	Carcinoma.	
Idiopathic.		

The treatment of a foul breath consists essentially in discovering, and, if possible, removing the cause. In by far the largest number of cases the origin of the trouble resides in digestive disturbances, usually associated with constipation, or in carious or dirty teeth. The first care of the physician should be, therefore, to regulate the digestive functions, and to see that the hygiene of the mouth is properly attended to. If the gums are spongy or receding, a tooth wash containing myrrh should be used. All cavities should be plugged with gold or some other suitable filling, as the dentist may advise, and the tartar, which accumulates between and behind the teeth, should be removed from time to time. The teeth should be picked, after each meal, to remove the particles of food, or, better still, they should be cleansed by means of dental floss, and should then be brushed with plain water, soap and water, or a reliable dentifrice. If the stomach is at fault, in addition to the remedies suitable to the condition, a piece of charcoal cake or charcoal powders may be taken shortly after meals. An odor which cannot be removed may be more or less effectually disguised by oil of nutmeg, cinnamon, cardamom seed, cloves, pimenta, lavender water, sweet-flag, leaves of the common partridge berry, or allspice, coffee, and other aromatics. A solution of carbolic acid (1 to 200) may be used as a mouth wash or gargle when the fœtor is due to organic destruction of tissue. The following is an agreeable mouth wash which will often disguise unpleasant odors: Thymol, 0.50 gm. (7½ grains); borax, 1 gm. (15 grains); distilled water, 500 gm. (1 pint). The mouth is to to be rinsed frequently with this solution.

For persistent foul breath, Howe advises the following combination. In the first place, the teeth should be thoroughly cleansed and the gums sponged with a solution of myrrh and water; then one of the following wafers may be allowed to dissolve in the mouth

℞ Pulv. cinnam.,	
Pulv. pimentæ,	
Pulv. cardam.	āā ʒ ss.
Sacchari alb.	ʒ i.
Mucil. gum acaciæ	q.s.

Make fifty pills.

In conjunction with these wafers, the following may be employed.

℞ Pulv. carui sem.,
Pulv. coriandri sem.,
Pulv. cinnam........................āā ʒ ss.
Sacch. alb.............................℥ i.
Mucil. gum. acaciæ...................q. s.

Make fifty pills. Dissolve one in the mouth when necessary.

All these deodorizers are, however, of necessity merely palliative in their effects, and the cause should always, if possible, be searched for and removed.

In the preparation of the foregoing article the present writer has made free use of the material published under the same heading in the previous edition.

Emma E. Walker.

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BRIDES-LES-BAINS is a spa in Savoy, France, often called, because of the composition of its waters, the French Carlsbad. Until recently the place was practically inaccessible, the nearest railway station being 20 miles away. Now, however, the railroad has been extended and there is a station at Moûtiers, distant only 3 miles. The village is most picturesquely situated, at an altitude of 1,800 feet above sea level, in a valley running from southeast to northwest, enclosed on either side by almost precipitous mountain slopes.

Access.—The station of Moûtiers is on the Paris, Lyons, Mediterranean Railway, 672 miles, or 13 hours, from Paris; fare, 75 fr. 35 c. first class, and 50 fr. 90 c. second class.

Analysis.—The following is the composition of the water, according to an analysis made by Willm in 1890:

	Grams, per litre.	Grains, per pint.
Carbonate of calcium	0.3133	2.7752
Carbonate of magnesium	.0112	.0992
Carbonate of iron	.0078	.0692
Silica	.0464	.4108
Chloride of sodium	1.8318	16.2244
Sulphate of sodium	1.1604	10.2836
Sulphate of potassium	.0946	.8380
Sulphate of lithium	.0095	.0840
Sulphate of calcium	1.7143	15.1940
Sulphate of magnesium	.5288	4.6836
Arsenate of sodium	.0008	.0071
Phosphates, bromides, iodides	Traces.	Traces.
Carbonic acid forming bicarbonates	.2934	2.6012
Free carbonic acid	.1017	.9008

Indications.—The waters of Brides are in moderate doses laxative, in larger quantities (six to eight glasses daily) purgative. It is claimed that they can be taken for many days in succession without increasing the dose, and they do not irritate to the same degree as do many of the stronger purgative waters. They are used in various disorders of the abdominal viscera, such as congestion of the liver following dietetic imprudences or alcoholic excesses or a prolonged residence in the tropics, gall-stones, constipation, functional disturbances of the digestive tract, obesity, the so-called uric-acid diathesis, gravel, diabetes, anæmia and chlorosis, and chronic con-

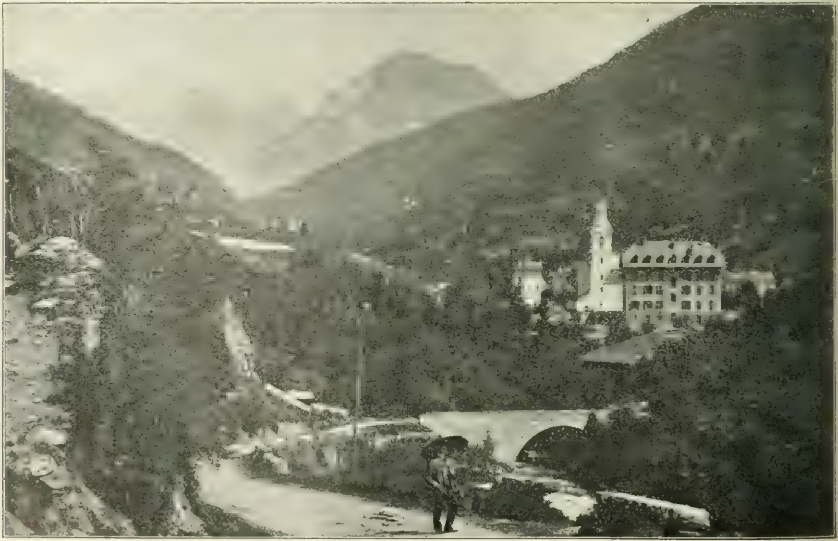

FIG. 1052.—Brides-les-Bains and the Glaciers of the Vanoise.

gestion of the uterus and adnexa. In many cases treatment with Brides water internally is combined with baths at Salins-Moûtiers, distant two miles from Brides.

Accommodations.—There are four hotels at Brides, in addition to numerous boarding houses, which afford good and ample accommodations at from six to eight francs and upward a day. A casino, music in the park, and the usual attractions of the continental spa are to be found here. There are two churches, a Catholic and a Protestant, the latter being served by an English clergyman during the season. The climate is mild, but not enervating. The season extends from the middle of May to the middle of September.

SALINS-MOÛTIERS.—This is a small thermal station in Savoy, France, distant 672 miles from Paris, on the Paris, Lyons, Mediterranean Railway. It is situated in a narrow valley in a grandly picturesque country, at an elevation of about 1,500 feet above the level of the sea. It is 2 miles from Brides-les-Bains, with which it is connected by an electric railway.

Analysis.—The following is the composition of the water, according to an analysis made by M. Willm, Professor of Chemistry at Lille, in 1890:

	Grams, per litre.	Grains, per pint.
Carbonate of calcium	0.6488	5.8392
Carbonate of magnesium	.0089	.0801
Carbonate of iron	.0136	.1224
Silica	.0332	.2988
Chloride of sodium	12.4886	112.3974
Chloride of potassium	.1695	1.5255
Sulphate of lithium	.0046	.0414
Sulphate of calcium	2.0638	18.5742
Sulphate of magnesium	.8460	7.6140
Arseniate of sodium	.0007	.0063
Phosphates, bromides, iodides	Traces.	Traces.
Organic matters and losses	.0192	.1728
Carbonic acid forming bicarbonates	.5906	5.3154
Free carbonic acid	.3854	3.3486

Indications.—The waters of Salins-Moûtiers are employed chiefly for bathing, usually in connection with the internal use of the water of Brides-les-Bains, but they are also taken internally in special cases. According to D. W. Samways, "for young people with enlarged glands, anæmia, chlorosis, or general lack of vigor, these baths are excellent, especially in conjunction with the climatic advantages of the locality. For the overworked or neurasthenic, for those also in whom convalescence is tardy, they are similarly very reviving. For such cardiac affections as can be relieved or controlled by baths and exercises similar to those in vogue at Nauheim, and for certain congestions and disorders of the uterus and its appendages they are also very beneficial."

Accommodations.—There is a hotel at Salins-Moûtiers, and there are also many boarding houses in the village where guests may find suitable accommodations. Most of those who take the baths, however, do so in conjunction with the internal use of the waters of Brides-les-Bains, and live at the latter place. The climate is mild but invigorating. The season lasts from the middle of May to the middle of September.

Edward O. Otis.

BRIGHT'S DISEASE. See *Kidneys, Diseases of the.*

BROMAL HYDRATE.—C_2HBr_3O,H_2O. Like chloral, *bromal* is an oily fluid which, uniting with water, forms a crystalline hydrate. Bromal hydrate occurs in white crystalline masses of a sharp, burning odor and taste, fusible at 53.5° C. (128.3° F.), and soluble in water. Physiologically the drug is severely irritant, and, absorbed into the circulation, has been found by experiment (Steinauer) to cause restlessness followed by sleep, and, if the dosage be pushed, dyspnœa, convulsions, and death. It may relieve pain, and has been thought to be of avail in averting threatened epileptic fits, but it is not official in the United States Pharmacopœia and is little used in medicine. It has been given in three-grain doses (Steinauer), but it is so disturbing to the digestive functions that the dose must be given in great dilution.

Edward Curtis.

BROMALIN.—Hexa-methylene-tetramine-brom-ethylate; brom-ethyl-formin—$(CH_2)_6NHC_2H_5Br$—made by acting upon hexamethylene tetramine with ethyl bromide. It is in colorless scales or a white crystalline powder, almost tasteless and freely soluble in water. It is decomposed by heat. Bromalin was introduced to take the place of the alkaline bromides in epilepsy, and may be used in other conditions in which bromides are indicated. The dose is gr. xv.–lx., and even large quantities are said not to cause bromism. *W. A. Bastedo.*

BROMAMIDE. — Tri-brom-aniline-hydrobromide — $C_6H_2Br_3.NH_2HBr$—nitro-tri-benzol is reduced by nascent hydrogen and then acted upon by hydrobromic acid to form bromamide. It occurs in colorless acicular crystals without odor or taste and is readily volatilized by heat. It is insoluble in cold alcohol, soluble in sixteen parts of boiling alcohol, and in chloroform, ether, and fixed oils. As an analgesic, sedative, and antipyretic it has been shown to act promptly and effectively in acute and chronic rheumatism and neuralgia. Dose: gr. v.–xv. in powder or capsule several times a day. *W. A. Bastedo.*

BROMELIACEÆ.—A family of some forty genera and probably five hundred species, almost entirely tropical, in both hemispheres, a few sub-tropical. The family, by virtue of its structure, epiphytic habits and relations, is one of the most interesting known to botanists, and very many of its members are highly ornamental. Its economic importance is considerable. The pineapple is its most important product. The leaves of many species are important fibre-yielders, and the well-known "Florida moss" or "black moss" (*Tillandsia usneoides* L.) has many uses. The dissolving power of pineapple juice upon albumen has been utilized in diphtheria to a slight extent. Its value as an aid to stomach digestion is probably of far greater importance, and the same property appears to exist in some of the leaf juices.

Henry H. Rusby.

BROMIDES.—1. GENERAL MEDICINAL PROPERTIES OF THE BROMIDES.—Compounds of bromine, whose basylous radicle is innocuous enough to permit of their medicinal administration in decided quantity, all show a certain influence over the animal system, commonly, and undoubtedly rightly, referred to the action of the bromine of their composition. Of the effects, the most striking feature is derangement of nerve function, which, in moderate dosage, takes the form of a deadening of reflex irritability, cerebral and spinal, and in poisonous administration shows itself as failure of power, voluntary as well as reflex, in the cerebro-spinal centres. Clinically, the prominent effects are that the nervous, agitated, and wakeful subject becomes calm, tranquil, and predisposed to sleep; that convulsive seizures, the expressions of unnatural reflex irritability, such as the convulsions of epilepsy and of tetanus, tend to abate in frequency and violence; that a qualmish stomach becomes quieted, that tickling of the fauces fails to provoke gagging, and that sexual eagerness and even power wane. In profounder bromism what was at first intellectual laziness and indifference becomes positive stupidity, with failure of memory and with or without a certain grade of aphasia; what was a dulness of reflex activity passes to motor and sensory weakness—paresis of sight, hearing, and tactile sense and profound muscular debility, until at last, after apparently total abolition of all conscious existence, the poisoned subject dies, either from respiratory or from cardiac failure. Minor effects, in cases of continuous bromide medication, are a peculiar fœtor to the breath, a tendency to an acneiform eruption, most pronounced on the face, arms, back, and buttocks, and a tendency to congestion and even œdema of the fauces and uvula, and, later, of the conjunctiva also. All of these various symptoms, formidable though many of them are, rapidly abate upon discontinuance of the medicine, and, as a rule, leave no permanent morbid results Other effects, notably derangement of the circulation and lowering of body temperature, are observed in the operation of the most commonly used bromide, namely, the potassium salt, and also in that of the closely allied lithium bromide; but inasmuch as these are effects which are more or less common to all salts of potassium and lithium, it is an open question whether their occurrence in the present connection is not due rather to the basylous element of the bromide than to the bromine. Bromides are quick of absorption, and, generally speaking, fairly quick of elimination, and in such elimination are to be found in all the secretions—urine, fæces, sweat, saliva, and even in the pus of the acne pustules.

The most interesting effect of bromides, namely, the derangement of function of the cerebro-spinal nervous system, has been made the theme of much experimentation for the purpose of finding just where the bromide influence strikes. As usual, the experiments are not wholly in accord, but their general drift clearly indicates, as H. C. Wood points out, that the deadening of functional activity occurs first and most severely in the peripheral ends of the afferent nerves and those portions of the axis that have to do with the reception of sensory impressions and their transmission as an impetus for motor reflex response. Later, and to a proportionately lesser degree, are affected the motor tract of the cord and the motor nerves. By this hypothesis is rendered intelligible the oft-observed occurrence that a bromized frog, while profoundly indifferent to pricks or searings, from evident cutaneous anæsthesia, may still retain enough command of motor power to hop, and vigorously, too, at will.

The *therapeutics* of the bromides consist of the direct application, for clinical ends, of the bromine influence to blunt nervous impressibility. Such displays of nervous excitement as are the expression of a state of direct morbid irritation of the nervous system, in whole or in part, are conditions proper for the action of a bromide; but, on the other hand, the derangements of nerve function caused by *exhaustion*, general or local, are distinctly *not* to be treated by bromine medication For in such latter case, because of the generally depressing character of the bromine influence, the exhaustion will be deepened, and the nervous symptoms, therefore, intensified. Prominent illustrations of the conditions in which bromides may be of benefit are undue restlessness and wakefulness, or mental irritability or morbidness from any emotional cause, or from severe intellectual labor under pressure; undue excitability of a lusty sexual apparatus from too free indulgence; and, more notable still, expressions of reflex action, such as the convulsions of epilepsy, of tetanus, or of strychnine poisoning; the convulsions of children, seasickness, or the vomiting of pregnancy or of neurotic poisoning. Conditions in which, on the other hand, bromides are useless or harmful are restlessness, wakefulness, or mental derangement from want of sleep, from starvation, from loss of blood, or devitalization from a prostrating disease, such as typhoid fever, or, locally, irritability of the sexual organs when associated with beginning of failure of power through exhaustion from excessive abuse. In cases for which bromides are fitting it is hardly necessary to say that the remedy will promise more if resorted to at the outset, and that large doses may conquer where small ones will utterly fail. In chronic and intractable disease, such as epilepsy, two points, besides sufficiency of dosage, must be observed, as follows: *First*, the blood must be kept evenly and continuously charged with the bromide salt. And, by reason of the rapid elimination of the salt, this result can be secured only by giving the daily allowance in at least three doses, whereof the evening one, having longer to last, should be larger than the others. *Secondly*, the medication must not be too speedily discontinued after apparent cure of the malady, but, on the contrary, must be kept up for months, and even years, thereafter. In epilepsy, it is singular that the form of the disease called *petit mal* should be, as it is, distinctly less amenable to bromide medication than the classical form in which the fits are outspoken. In epilepsy, when the disease is recent and of the latter variety, the curative power of the bromides surpasses that of any other drug; but, as a rule, the remedy will have to be pushed to the development of a certain grade of bromism before benefit appears.

2. THE BROMIDES USED IN MEDICINE.—The bromides official in the United States Pharmacopœia are, among bases of the heavy metals, *zinc* bromide, and among those of the alkali metals and metals of the earth, *potassium*, *sodium*, *lithium*, *ammonium*, *strontium*, and *calcium* bromides. *Hydrobromic acid* and *brominated camphor* also may be mentioned as being, logically, bromides, and furthermore as showing in their action upon the animal system the peculiar bromine influence in addition to their other effects. Lastly, an ethereal bromide, namely, *monobromethane* ("bromide of ethyl," "hydrobromic ether"), although not official, has been used in medicine as an anæsthetic. In the present article will be discussed only the bromides of the metals of the alkalies and earths, in which alone the bromine influence is the dominant medicinal virtue. For zinc bromide, see *Zinc;* for hydrobromic acid, see *Hydrobromic Acid;* for brominated camphor, see *Camphor;* and for ethyl bromide, see *Ethyl Bromide.*

Potassium Bromide: KBr.—Potassium bromide is official in the United States Pharmacopœia as *Potassii Bromidum*, Potassium Bromide. It occurs in "colorless or white, cubical crystals or granules, odorless, and having a pungent, saline taste. Permanent in the air. Soluble, at 15° C. (59° F.), in about 1.6 parts of water, and in 200 parts of alcohol; in less than 1 part of boiling water, and in 16 parts of boiling alcohol; also soluble in 4 parts of glycerin. On heating the salt upon platinum foil, it decrepitates; near 700° C. (1290° F.) it fuses without decomposing, and at a bright-red heat it volatilizes, communicating a violet color to the flame. The aqueous solution (1 to 20) is neutral, or has at most only a scarcely perceptible alkaline reaction upon litmus paper" (U. S. P.). In some commercial samples the alkalinity is said to be decided, sufficiently so to enable the salt to precipitate alkaloids from solutions of their salts.[1] Potassium bromide should be kept in well-stoppered bottles.

Potassium bromide is the most generally active, the best known, and the most commonly prescribed bromide. It is capable of producing to the highest degree the peculiar bromine effects already detailed, and also has a marked influence over the circulatory organs, and, if pushed to poisoning, a power distinctly to lower body temperature. The circulatory derangement consists first in a slowing and weakening of the heart's contractions, passing even to stoppage of the organ in diastole; and, secondly, a probable—but probable only—narrowing of the lumen of the smaller blood-vessels, through vasomotor spasm. Partly because of the effect upon the heart, and partly also because of the presumed effect upon the blood-vessels, potassium bromide is commonly held to induce partial capillary anæmia, especially of the nerve centres—spinal cord and brain. And because of this anæmia, in turn, it has been imagined by some, and become quite a text-book tradition with many, that the action upon the vascular organs is the only direct one that potassium bromide exerts, all the nervous phenomena being sweepingly accounted for as mere secondary consequences of a diminished blood supply to the cerebro-spinal axis. To refute this notion it seems only necessary to cite on the one hand the fact that other bromides than the potassic which have but little of the depressing effect of the latter salt upon circulation yet show the bromine influence over nerve function, and, on the other hand, to note that cerebro-spinal anæmia, occurring as it can easily be made to do experimentally by other methods and to any degree, is, when so determined, never followed by the peculiar phenomena of bromism.

As the drug is medicinally given, the clinical effects of potassium bromide are a salty taste in the mouth, with a little increase in the flow of the saliva, and perhaps also some diuresis, an abatement of all forms of nervousness, fidgets, or even spasms, with a tendency to mental calm and indifference, intellectual and physical sloth, and, if circumstances favor, drowsiness. Along with these suggestive symptoms the pulse falls somewhat in force and frequency. If the dose has been single and not overlarge, little other than the foregoing effects will be declared; but, if the taking be continuous and the doses range high, the derangement may be profound, the subject presenting the picture of one mentally dull even to idiocy, with perhaps some aphasia; dull of hearing, sight, and feeling; physically weak even to paresis, sexually impotent, and with the peculiar symptoms of a fœtid breath, a whispering voice, a face broken out in acne, a congested or even œdematous faucial arch, a slow and failing pulse and respiration, and a depressed body temperature. In overwhelming dosage, paralysis of sense and motion becomes absolute, and death ensues quietly by failure of respiration or of cardiac action—the former if the poisoning has been progressive by accumulating small doses, the latter if by a single overpowering charge. But, as usual with the bromides, so long as the condition is one short of death, the symptoms quite certainly will ameliorate—and that, too, without lasting results—upon stopping the medication. In case of serious poisoning, the treatment must be in accordance with general principles, consisting in evacuation of the stomach, if a large single dose has been taken, and, for the rest, the employment of measures addressed to maintaining the action of the heart and lungs.

Potassium bromide is used, medicinally, exclusively for the peculiar purposes of the bromides generally, as set forth in the first section of this article. When the need is transient only, as to quiet a squeamish stomach, or to calm a restless subject and invite sleep, the dose will range from 1.3 to 3 gm., or thereabouts (gr. xx. to xlv.), according to the intensity of the disturbance and the susceptibility of the individual. When, on the other hand, a continuous and powerful impression is necessary, as in treating epilepsy or tetanus, the doses may have to be both large and frequent. In dealing with epilepsy, the daily quantity will rarely be less than 6 gm. (gr. xc.) and may need to reach 15 gm. (half an ounce), given broken up into three or four doses evenly distributed over the waking hours, excepting as to the evening portion, which should be somewhat larger than the others. The actual dosage in a given case must be determined by the effects produced upon the fits. A clinical rule with some is to give the salt until the usual reflex gagging, occurring upon tickling the fauces, is found to be abolished. Even with the smallest daily quantity above named a certain degree of "bromism" will follow the continuous giving, and such result must be expected. Rarely indeed will any impression be made upon the epilepsy until some bromism shows itself. In tetanus or strychnine poisoning the dosage of bromide reaches its maximum. Here the extraordinarily heightened reflex irritability which is the essence of the morbid condition in the two affections makes the subject comparatively insusceptible to the benumbing influence of bromine. Even so large a dose as 15 gm. (half an ounce) has been given at a single draught, and the daily total should certainly reach this figure. Yet in strychnine poisoning it must be remembered that the tetanus, if it does not kill within a couple of hours, then rapidly abates, and simultaneously, of course, disappears the insusceptibility to bromide influence. Care must be taken, therefore, to diminish the bromide dosing, as the morbid irritability fades, else, as has actually happened, the subject may be saved from death by strychnine convulsions only to be brought to the verge of the grave by bromide palsy. Potassium bromide is administered in solution either in simple iced water or, what is pleasanter and in case of large doses makes the draught less obnoxious to the stomach, in water slightly alkalized by the addition of a little sodium bicarbonate, or, best of all, in water both alkaline and effervescent, such as Vichy [2] or Apollinaris.

Sodium Bromide: NaBr.—The salt is official in the United States Pharmacopœia as *Sodii Bromidum*, Sodium Bromide. It occurs in "colorless or white, cubical crystals, or a white, granular powder, odorless, and having a saline, slightly bitter taste. From air the salt attracts moisture without deliquescing. Soluble, at 15° C. (59° F.), in 1.2 parts of water and in 13 parts of alcohol, in 0.5 part of boiling water and in 11 parts of boiling alcohol. When heated to a bright red heat the salt melts, and, at a somewhat higher temperature, slowly volatilizes without decomposition. To a non luminous flame it imparts an intense, yellow color. The aqueous solution is neutral, or at most very feebly alkaline, to litmus paper" (U. S. P.). Sodium bromide is hygroscopic, and should be kept in well-stoppered bottles.

Sodium bromide is less unpleasant to taste than the potassic salt, and is in every way less deranging of function. But yet, despite the fact that its innocuousness permits of its prescription in larger doses and for more continuous administration than may be possible with potassium bromide, the bulk of testimony goes to show that the sodic salt is of distinctly inferior curative power. Its use is, therefore, properly confined either to cases in which but a mild effect is called for, or to those in which, for any reason, the potassic salt cannot be given, or having been given must be abandoned. The fact that, weight for weight, the sodic bromide contains more bromine than the potassic (in the proportion of 77.62 to 67.13) simply shows the more forcibly the intrinsic physiological feebleness of the compound. Sodium bromide should be given in the same manner as the potassic salt, and in the same dose, carefully to be augmented according to the effects produced.

Lithium Bromide: LiBr.—The salt is official in the United States Pharmacopœia as *Lithii Bromidum*, Lithium Bromide. It occurs as a "white, granular salt, odorless, and having a sharp, slightly bitter taste; very deliquescent. Soluble, at 15° C. (59° F.), in 0.6 part of water and in 0.3 part of boiling water; very soluble in alcohol; also soluble in ether. At a low red heat the salt fuses, and at a higher heat it is slowly volatilized. It imparts a crimson color to a non luminous flame. The aqueous solution is neutral to litmus paper" (U. S. P.). Being exceedingly deliquescent, this salt should be kept in well stoppered bottles.

So far as observed, lithium bromide very closely resembles the potassic salt in its effects, as the nature of its base would render likely. Dr. S. Weir Mitchell, of Philadelphia, who first advocated this bromide for use in the nerve affections for which potassium bromide is commonly prescribed, considers the lithic salt more speedily and more powerfully hypnotic than the potassic. It has the demerit of comparative costliness. It contains proportionally more bromine than does any other of the alkaline bromides, and has been recommended in one-half the dose of the potassic salt (Weir Mitchell).

Ammonium Bromide: NH_4Br.—The salt is official in the United States Pharmacopœia as *Ammonii Bromidum*, Ammonium Bromide. It occurs as "colorless, transparent, prismatic crystals, or a white, crystalline powder, odorless, of a pungent, saline taste, and permanent in the air. Soluble, at 15° C. (59° F.), in 1.5 parts of water and in 30 parts of alcohol; in 0.7 part of boiling water and in 15 parts of boiling alcohol. When heated, the salt volatilizes completely without melting. The aqueous solution of the salt has a slightly acid reaction upon litmus paper" (U. S. P.).

From the point of view of the clinician, ammonium bromide may be regarded as substantially a duplicate of potassium bromide in medicinal virtues, while at the same time more acrid in taste and in local action. It has been used for the same purposes as the potassic salt, and in the same dose, and has been strongly recommended by Brown-Séquard and others in epilepsy. It is less depressing than potassium bromide.

Strontium Bromide: $SrBr_2,6H_2O$.—The salt is official in the United States Pharmacopœia as *Strontii Bromidum*, Strontium Bromide. It is in "colorless, transparent, hexagonal crystals, odorless, and having a bitter, saline taste. Very deliquescent. Soluble in 1.05 parts of water at 15° C. (59° F.) and in 0.5 part of boiling water. It is readily soluble in alcohol, and is precipitated from this solution upon the addition of an equal volume of ether, in which it is insoluble. When heated the crystals at first melt and then lose all their water (30.4 per cent.). The anhydrous salt fuses at 630° C. (1166° F.). To a non-luminous flame the salt communicates an intense, red color. The aqueous solution is neutral to litmus paper" (U. S. P.) Owing to the extreme deliquescence of this salt it should be kept in well stoppered bottles

As in the case of the strontium salts generally, this one closely resembles in its effects on the animal system its potassic congener Compared with potassium bromide, however, strontium bromide is the better borne, having less tendency to derange digestion or to bring on the special symptoms of bromism. It may be prescribed in the same doses and for the same purposes as the bromides generally.

Calcium Bromide: $CaBr_2$.—The salt is official in the United States Pharmacopœia as *Calcii Bromidum*, Calcium Bromide. It is a "white, granular salt, odorless, of a sharp, saline taste, and very deliquescent. Soluble, at 15° C. (59° F.), in 0.7 part of water and in 1 part of alcohol; much more soluble at a boiling temperature. At 680° C. (1256° F.) the salt fuses, and at a higher temperature it is partly decomposed, with loss of bromine. The salt is neutral to litmus paper" (U. S. P.). The salt must be kept in well-stoppered bottles.

Calcium bromide does not seem to differ materially in properties from potassium bromide, and stands in medicine as an additional and not over-necessary substitute for the same, in the same range of application and in the same dosage. It was originally proposed by Dr. W. A Hammond, in 1871. *Edward Curtis*

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[1] U. S. Dispensatory, 18th edition, quoting Charles D. Chase.
[2] Seguin: Archives of Medicine.

BROMIDIA is a proprietary remedy which is stated to contain in a fluiddrachm Chloral hydrate and potassium bromide, of each gr. xv., and gr. $\frac{1}{8}$ each of the extracts of cannabis indica and hyoscyamus Analyses indicate that it also contains oil of orange peel and extract of licorice *W. A. Bastedo.*

BROMIDROSIS. — (Bromhidrosis, Osmidrosis; Ger. *Stinkender Schweiss.*) Bromidrosis, as a disease *per se*, is a pathological variation in the odor-producing constituents of the sweat *as secreted*, is associated as a rule with the functional disorder of the sweat apparatus, hyperidrosis, and, like it, may be either local or general. This condition as such, if it occurs at all, is rare.

The condition ordinarily denominated bromidrosis is due, as was taught by Hebra to be the case in the majority of instances, to a rapid decomposition of the sweat *after* its secretion, with the resultant odor, warranting the term stinking applied to it.

When local, as is more commonly the case, the regions affected are those in which sweating oftenest occurs in excess and in which its quick evaporation is more or less retarded or prevented by the nature of the parts or their covering, as the axillæ, groins, ano-genital region, and the feet—the last being by far the most frequent situation of the affection. Here the odor is marked and most characteristic, differing from the odor of other parts affected by its unmistakable, nauseating heaviness when once recognized—and one whiff is all sufficient,—the foul emanation rendering the near neighborhood of the unfortunate victim anything but pleasant, and sometimes impossible.

The change that takes place in the sweat is claimed to be due to the presence of a special micro-organism—the bacterium fœtidum, a micrococcus which Thin, of Prague, recognized in sweat obtained from the feet. It has been shown by Parkes that soldiers with uncovered feet do not suffer from this affection, and he claims that the only cause of the disease, if such it can be called, is the covering of the feet, the absence of all coverings giving no opportunity for the development in the secretions of the special bacterium

Treatment in general is linked with that of hyperidrosis. A level teaspoonful of the precipitated sulphur in milk twice daily has been highly recommended It is an empirical remedy, the action of it not being explained by Crocker, who claims to have succeeded more often by this than by any other procedure, local treatment not being necessary with it. However, dusting finely powdered boric acid well in between the toes and rubbing it into the stockings and shoes daily will be found as efficient, cleanly, and convenient a local method as any yet devised. and some local treatment will generally have to be resorted to Hot water applied as hot as can be borne for a few minutes before using the boric acid is a great aid

If the sulphur treatment purges too freely, its action may be controlled by astringents In five to ten grain doses salicylate of soda may be found useful. This may be tried when patients object to the sulphur It has cured some cases. Among other local remedies may be mentioned chromic acid; painted on the feet in five to ten per-cent. solution, according to the obstinacy of the case, every three to six weeks, it has been used successfully. Mutton suet with two per-cent. salicylic acid is in general use in the German army for rubbing on the feet, and further has the advantage of a lubricant when much walking is to be done. Formalin in one to ten per-cent. strengths in alcohol is of value It should be followed by the use of dusting powders A one-per-cent. solution of permanganate of potash has been well recommended. Various other remedies are extolled, but the boric acid will be found the best of all if preceded by the hot-water applications. *Charles Townshend Dade.*

BROMINE.—Bromine is official in the United States Pharmacopœia as *Bromum*, Bromine It is described as "a heavy, dark, brownish red, mobile liquid, evolving, even at ordinary temperatures, a yellowish-red vapor, highly irritating to the eyes and lungs, and having a peculiar suffocating odor, resembling that of chlorine. Specific gravity, 2.990 at 15° C. (59° F.), soluble in 30 parts of water at 15° C. (59° F.), and readily soluble in alcohol or ether (with gradual decomposition of these liquids). also in carbon disulphide, and in chloroform, with a deep reddish yellow color. On exposure to air or to heat it is completely volatilized" (U. S. P.). Bromine has the same intense affinity for hydrogen that has chlorine, and so, in similar manner to chlorine, determines the oxidation of organic matter in the presence of moisture by appropriating the hydrogen of the water and liberating the oxygen The fumes of bromine are thus deodorant, like chlorine, and if present in an atmosphere in great volume would doubtless prove destructive to floating disease germs Mixed directly with foul-smelling or infectious matter, bromine is powerfully deodorant and disinfectant. Yet practically it is of little use in such capacity, by reason of its costliness, its bad smell, its caustic and bleaching tendency, and the exceedingly irritant action of its vapor upon the human air passages. Squibb estimates that an ounce of bromine, accidentally spilled in an ordinary chamber, would render the air thereof dangerous to life.

Locally applied to living animal tissues, pure bromine is a very searching and painful caustic, and non-caustic dilutions act as detergent and stimulant lotions to foul or sloughing ulcers. Here again, however, the cost of the remedy and its offensiveness render it less practicable than its efficiency would suggest For caustic purposes, bromine is applied clear, the patient being etherized, if the area to be cauterized is at all extensive, and the operator taking care that his eyes and nose do not come too near the fumes of the very volatile and pungent liquid. For a strong lotion, a ten per-cent. solution in water may be employed, wherein the bromine is made to dissolve by the addition of one-third of its weight of potassium bromide. For weaker lotions—any percentage less than three—bromine is directly soluble in water without any saline addition. Taken internally, bromine is doubtless absorbed as a bromide. It was formerly used as an internal medicine in the class of diseases for which iodine or the alkaline iodides are now so extensively employed For the specific purposes of the alkaline bromides (see *Bromides*), bromine is practically unavailable, because of its irritant action and offensive taste. Bromine has been given internally in the dose of from three to six drops of a two-and-a-half-per-cent. aqueous solution

Toxicology.—Bromine is an intensely irritant, corrosive poison. The fumes, inhaled, produce extreme irritation of the eyes, the air passages, and even the stomach. Severe bronchitis, pulmonary hemorrhage and inflammation, and death may result. Swallowed in overdose, bromine produces the usual symptoms of the corrosive poisons, viz., intense gastric irritation, collapse, and death. A half-ounce of bromine, swallowed, produced death in seven and a half hours. In case of poisoning by inhalation, the local irritation should be treated by the breathing of the atomized spray of an alkaline solution, such as Dobell's solution. In poisoning by swallowing, the stomach must be washed out and ammonia given, largely diluted and mixed with olive oil

Edward Curtis

BROMINE-ARSENIC SPRINGS.—Ashe County, North Carolina

Post-Office —Crumpler Hotel

Access.—Via Norfolk and Western Railroad to Chilhowie, Va., thence 39 miles by stage to the springs; also by private conveyance from Bristol, Tenn., 34 miles west.

This spring was discovered in 1885. Since that time it has come into extensive use, and its waters are widely sold. The location of the spring is in a mountainous district, 2,725 feet above the sea level. There is a hotel with accommodations for about one hundred persons at the resort. The spring flows about sixty gallons hourly. The following analysis was made by Prof Henry Froehling·

Solids.	Grains.
Sodium carbonate	1.04
Calcium carbonate	.93
Magnesium carbonate	.62
Lithium carbonate	.03
Copper carbonate	Trace.
Zinc carbonate	Trace.
Calcium fluoride	Trace.
Potassium sulphate	.62
Potassium chloride	.21
Sodium chloride	.65
Sodium arsenate	Trace.
Sodium iodide	Trace.
Sodium bromide	.04
Sodium borate	Trace.
Aluminum phosphate	.12
Iron sulphate	.08
Silica	1.08
Organic matter	.03
Total	5.45

The water is unique in possessing recognizable quantities of copper and zinc. It also contains the somewhat rare ingredients of arseniate of sodium and the iodide and bromide of sodium. We also find an appreciable amount of carbonate of lithium and sulphate of iron. The water is not highly mineralized, but it possesses valuable qualities as a mild antacid, tonic, and alterative. It is useful in many of the affections benefited by this class of waters *James K. Crook.*

BROMINE CHLORIDE.—By direct union of the two elements, bromine and chlorine, a compound is formed appearing as a reddish-yellow, volatile, mobile fluid, soluble in water This compound is powerfully caustic, but has never been used in regular medicine except as an ingredient of a caustic paste used by Landolfi, of Naples, for the treatment of cancer. *Edward Curtis.*

BROMIPIN is an addition product of oil of sesame, containing ten per cent. of bromine It is a yellow fluid having the appearance of a fixed oil, and it has a bland, oleaginous taste In spite of the large amount of bromine which it contains, the oil is non irritating and may be given pure by mouth. It is readily absorbed and its action is of the same character as that of the alkaline bromides. Losio claims that it surpasses potassium bromide in chorea, epilepsy, and trigeminal neuralgia. Dornblüth found that one drachm given at the evening meal would ward off a night attack of cardiac palpitation or angina pectoris. The oily taste of bromipin is not pleasant, but very soon the taste is acquired, and the patients continue to take it for a long time without gastric or intestinal disturbance. The dose is one half to two drachms daily for restlessness and nervous irritability, for chorea or epilepsy, up to four drachms a day It may be administered pure and unmixed, or with beer, or mixed with cacao, sugar, white of egg, and oil of cinnamon A not unpleasant emulsion is made by taking two ounces of bromipin and emulsifying it with half an ounce of powdered acacia, half an ounce of syrup, and cinnamon or peppermint water to make four ounces, to be given in doses of from one to four drachms. *W A Bastedo*

BROMO-ALBUMIN is a ten per-cent bromine compound of peptone, albumose, or protogen. It is given in doses of from one-half to two drachms in epilepsy and other nervous conditions Its indications are the same as those of the alkaline bromides. *W A. Bastedo.*

BROMOFORM.—(Terbromide of formyl, $CHBr_3$) In chemical composition it is analogous to chloroform, $CHCl_3$, and iodoform, CHI_3. It is formed by the action of brominated lime on alcohol in the same way that chloroform is made from chlorinated lime and alcohol. It is a bright clear liquid, specific gravity 2 9, taste sweet, and does not cause any irritation to the mucous membrane of the mouth, it has an ethereal odor is almost insoluble in water, but is soluble in alcohol and ether. It is very volatile and is rapidly decomposed by light, bromine fumes being evolved which impart a pink color to the liquid

Bromoform possesses anæsthetic properties, but in a less degree than chloroform, the period of excitement being less pronounced and the anæsthesia of shorter duration. It is also a powerful antiseptic

A new application of this drug was brought to the notice of the profession in 1889 by Dr Stepp, of Nüremberg, who advocated its use in whooping-cough. He claimed that the course of the disease was shortened in every instance, that the paroxysms were diminished in number and severity, that complications were less frequent, and that when present they were benefited by the treatment. The doses which he gave at different ages were as follows From six months to one year, ♏ ij. three times a day; from one to two years, ♏ iij., from two to three, ♏ iv.; from three to four, ♏ v, and from four to seven, ♏ vi. or vij. In prescribing the remedy its high specific gravity must be remembered, one minim being equal to five drops

The drug is given in a teaspoonful of water· it forms a "bead" in the water and is easily swallowed. It may be given in solution in water to which a small amount of alcohol is added, but should always be freshly prepared on account of its instability. It should be employed with some caution, as ill effects have frequently followed its use. It has produced nausea, vomiting, and diarrhœa, and other symptoms of gastro intestinal irritation. The more pronounced toxic symptoms are pallor, cold perspiration, staggering, dilatation of pupils, heart failure, collapse, and a tendency to narcosis. Fatal cases have been reported (*Münch. medic. Wochensch*, xlv., 1211; *L'union méd.*, September, 1891).

Stepp's method of administration is not to be recommended, and many of the cases of poisoning are explained by the uncertainty of this dose. It is preferable to use it dissolved in alcohol. Compound tincture of cardamon and syrup of orange may be added. Another mixture that is recommended is an emulsion of bromoform with oil of sweet almonds, gum acacia, gum tragacanth, and syrup. All mixtures in which the drug is not dissolved are very uncertain, and require to be prepared with great care.

How the drug acts is uncertain; whether as a specific or on account of its germicidal properties, has not been determined. Dr. Stepp thinks bromine is excreted by the lungs after the drug has been decomposed in the system. The reports of others who have used it for this purpose corroborate the views of Dr. Stepp as to its efficacy in whooping-cough. *Beaumont Small.*

BROMOL.—(Tribromophenol.) This is formed by adding bromine water to a solution of phenol. It is deposited in white crystals; taste is sweet and astringent; odor resembles bromine; it is nearly insoluble in water. but is soluble in alcohol, ether, oils, and glycerin

It has been introduced as an antiseptic in the treatment of wounds, ulcers, etc. Applied in its pure state it has a slight caustic action and favors the removal of sloughs. As a dressing it is applied in solution in oil or as an ointment, one part in thirty. It has been used in diphtheria as a local application to disinfect the throat and remove the membrane.

When administered internally it is not acted on by the gastric secretions, and in the intestines is but slowly decomposed. Its action is therefore slow and prolonged. It is given in doses of gr. iij. to v. a day, and has proved of service as an intestinal antiseptic in cholera infantum and typhoid fever. For infants gr $\frac{1}{4}$ to $\frac{1}{8}$ may be given at each dose. *Beaumont Small.*

BRONCHI, MINUTE ANATOMY OF.—As a preface to the histology of the bronchi, a short résumé of the gross anatomy seems here desirable. The bronchi—more properly bronchia, *βρογχια*, meaning swallow or throat—probably received the name through Plato, who taught that their function was to receive the liquids, the œsophagus receiving the solids. Aristotle having supported this theory, the name remained so long in medical use as to become a fixture.

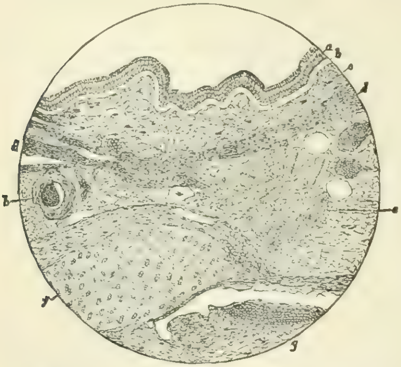

FIG. 1053.—Represents a Transverse Section of the Bronchial Wall at the Fifth Bifurcation in the Human Adult. *a*, Epithelial layer of mucous membrane; *b*, hyaline basement membrane, formed from *c*, internal elastic layer, showing its varying thickness; *d*, *d*, muscular layer; *e*, muciparous crypts; *f*, cartilaginous lamina; *g*, external layer; *h*, branch of bronchial artery. (About 30 diameters.) (Drawn with camera by Dr. F. Cary.)

The bronchia, beginning at the tracheal bifurcation opposite the third dorsal vertebra (fourth in female), terminate in the pulmonary lobules. The primary tracheal branches, from their distribution, are named the right and left bronchus. The former is shorter, larger, and more horizontal than the latter, and the septum bronchiale separating them is placed to the left of the longitudinal (in the recumbent posture of the body) axis of the treachea. Hence bodies falling into the trachea lodge more frequently in the right bronchus. Hyrtl teaches that post-mortem examinations of the new-born, dying after a few respirations, show that the right lung respires before the left, and he explains the fact by the difference in size and location of the beginning of the right bronchus. The general rule of dichotomous subdivision obtains, but is not without exception; *e.g.*, the right bronchus subdividing into three branches, one for each lobe. Occasional small branches are given off by the main trunk. Having reached the diameter of 0.21 mm. ($\frac{1}{120}$ inch), they enter the apices of the pulmonary lobules. Here again branching at acute angles they dilate slightly, becoming funnel-shaped, whence the name "infundibula vesicæ." (See article *Lungs.*)

STRUCTURE.—The bronchia are hollow, cylindrical tubes, which retain in structure, throughout a large portion of their extent, the characteristics of the trachea. Like the latter, they consist of four distinct layers: an external fibrous, a muscular, an internal elastic, and a mucous layer.

The *External Fibrous Layer* consists of a dense meshwork of connective tissue, in which are to be found rings or laminæ of hyaline cartilage. In the primary bronchia these are disposed as in the trachea, *i.e.*, in broken rings like the letter C, held together by fibrous bands. The ring is made complete by small transverse bundles of unstriped muscular fibres attached by microscopic tendons to the ends of the rings. By their contraction they increase the curvature of the cartilage and so diminish the calibre of the tube. The right bronchus contains six to eight of these cartilages; the left ten to twelve. Further removed from the trachea the cartilages gradually lose their ring-like shape, and are disposed in irregular polygonal laminæ. Becoming smaller and less frequent, they finally disappear in tubes of less diameter than 0.23 mm. ($\frac{1}{100}$ inch), the fibrous layer still continuing to form the external coat.

The *Muscular Layer* lies within the fibrous layer just described. It consists of separate bundles of unstriped muscular fibres, disposed for the most part transversely to the tube. It is better developed in the intervals between the cartilages than just beneath them. As the cartilages disappear this muscular layer becomes better and better developed, until at last it completely surrounds the bronchioles, which, on section, but for the epithelial lining, might be mistaken for arterioles. The muscular layer can be traced to the final branching of the bronchiole to form the alveolar passages, where, according to Rindfleisch, it becomes again better developed into a sort of "sphincter" at the point of entrance to the alveolar passages. The function of the muscular layer is to narrow the calibre of the tubes. This is only manifested to any appreciable extent in the bronchioles. The cartilages prevent any decided narrowing where they exist. In the experiments of Dr. C. J. B. Williams with electrical stimulation on bronchioles of less than a line in diameter, they were seen to contract until they nearly obliterated their lumen. Dr. Gairdner suggested that the contractility of the minute bronchioles may serve to expel collections of mucus which have accumulated in them, and which neither ciliary action nor the ordinary expiratory efforts would dislodge.

The Internal Elastic Layer.—Within the muscular layer, and beneath the mucous membrane, lie longitudinal bundles of elastic tissue quite regularly disposed. They project, as it were, partly into the lumen of the tube, and so give, on transverse section, a wavy, corrugated appearance to the lining membrane; on longitudinal section, a grooved or furrowed one. Piercing this as well as the muscular layer, chiefly in the bronchial tubes containing cartilages, are to be seen the muciparous ducts, lined with epithelium, leading inward to open on the free surface of the mucous membrane. The mucous crypts lie in the external fibrous layer, chiefly in the intervals between the cartilages.

The *Mucous Membrane* of the bronchia and bronchioles, forming the internal layer, possesses, throughout the greater portion of its extent, the characteristics of that of the tracheal mucous membrane. Like the latter, it consists of epithelial cells of the ciliated columnar variety, superimposed upon a basement membrane, which latter is made by a condensation of the inner part of the internal elastic layer. When the tube has reached the diameter of 0.2 mm. ($\frac{1}{50}$ inch), these cells lose their cilia, become shorter, smaller, and rounded, in the ultimate tubules becoming the simple pavement cells. Here the membrane loses its character as a mucous membrane, and resembles that which lines the alveoli (see article *Lungs*). Here and there in the larger tubes are to be found the cup-shaped cells (*Becherzellen*) of Schulze, the function of which is yet unknown.

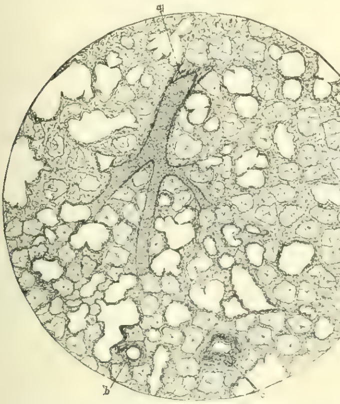

FIG. 1054.—*a*, A minute bronchiole splitting into the *ultimate* branches, which terminate in the alveolar passages; the epithelium has become of the simple pavement variety; on the left branch can be seen one of the so-called "saccular dilatations"; *b*, artery; *c*, medium-sized bronchiole having no cartilaginous lamina. The remainder of the field is normal lung tissue. (About 30 diameters.) (Drawn by Dr. F. Cary, from a microscopical section, with camera.)

Vascular Supply.—From the thoracic aorta are given off the bronchial arteries, which, receiving occasionally branches from the first intercostal and internal mammary arteries, accompany closely the subdivisions of the bronchia, supplying their walls, the walls of the large pulmonary vessels, the lymphatic glands, and the connective tissue of the lungs, to terminate finally in capillaries which inosculate freely with the respiratory plexus. Injections thrown into these vessels will fill also the capillary plexus of the arteria pulmonalis. The corresponding bronchial veins empty in part into the vena azygos, in part into the vena pulmonalis; the venous radicles from the ultimate bronchioles emptying into the latter, those corresponding to the arterial branches to the bronchia and lymphatics, into the former.

Lymphatic Supply.—The lymphatics arise in the alveolar septa. Stomata open on the alveolar walls between the epithelial cells, communicating thus directly with the alveolar cavity. They form a plexus in the submucous tissues, accompany the branches of the bronchia, as well as the pulmonary veins and arteries, emptying finally into the bronchial glands at the roots of the lungs. Within the lungs they often possess a gray or black speckled appearance, from the absorption of pigment or foreign bodies.

Nerve Supply.—The nerve supply to the lungs is derived from the pulmonary plexuses formed from branches of the vagus and sympatheticus. The filaments from these plexuses—situated at the lung hilum—follow the ramifications of the bronchia, becoming lost finally on them, and in the parenchyma of the lungs. When carefully stained they are seen to possess, in parts of their course, the microscopic ganglia to which Remak and Schiff first called attention.

The sensibility of the bronchia must be very slight; at least this seems to be true of their smaller branches, because of the slight complaint made by consumptives in whom large portions of bronchial and lung structure are being destroyed. *Lewis L. McArthur.*

BRONCHITIS.—In no affection is the practical importance of the distinction between acute and chronic disease better illustrated than in bronchitis. A bronchitis of recent origin or of sudden development is hardly the same disease as a bronchitis of long standing, because, aside from the fact that they both involve the same locality, and that cough is a leading symptom in both, the essential features in the course of each are quite dissimilar. Moreover, in acute bronchitis itself the conditions vary to such an extent, according to the part of the bronchial tract affected, that it will be more advantageous to consider so-called capillary bronchitis separately. Hence we prefer, in beginning with acute bronchitis, to restrict the term to that common affection known as an acute catarrh of the larger and medium-sized bronchi.

1. ACUTE BRONCHITIS. — *Symptomatology.* — Nearly every one in our climate has experienced the first stage, at least, of an attack of this complaint. When a catarrh of the upper respiratory tract has been severe enough to pass beyond the larynx and trachea and become a veritable bronchitis, though yet only extending to the primary divisions, the symptoms are then readily distinguishable at sight from any other cough producing affection. Pain is soon complained of and the patient's gesture in describing it is distinctive. Instead of applying his finger ends against one side, as he does to indicate the stitch or side stab of a pleurisy or a pneumonia, or holding his side as in pleurodynia, he lays his open hand on his breast as if taking an oath, and then passes it across the chest from side to side to indicate a suffocative sense of pain and tightness, which in severe cases feels as if the chest were transfixed with a disc of iron. Instead, also, of a carefully chosen and maintained decubitus, he changes frequently about, or else sits up and leans forward, a sure sign of a bilateral cause in dyspnœa, and one, therefore, which usually would exclude either a pneumonia or a pleurisy or phthisis. Although the patient may complain of difficult breathing, and although in active attacks he may breathe with both nostrils dilated, yet it will be noticed that, quite differently from what takes place in other febrile pulmonary affections, the respiration is but slightly accelerated; and, furthermore, the thermometer tells the same story in this as in inflammation of other mucous membranes, namely, that it rarely causes a greater rise than 100.5° to 101.5° F., unless some other element is entering into the course of the complaint. The other indications of a febrile complaint are usually present in a moderate degree also. The face is flushed, the eyes are watery, the voice is husky, the pulse somewhat faster than usual, the tongue furred, and along with a dry skin (not always) and headache there is also some chilliness, but not a distinct rigor, like that which ushers in a pneumonia.

The pain of bronchitis is an early symptom and often a sign that an acute catarrh, in its journey downward, has just entered the bronchi; for it is one of the peculiarities of the nervous supply of the respiratory tract that its sensitiveness differs markedly in different portions. The much greater irritability of the larynx over the trachea is well known, but it has been found by experiment that nearly the same proneness to cough on irritation is localized at the bifurcation of the bronchi. From this point onward, however, the irritability progressively diminishes until, as a result, serious accumulations of fluid may form in the smaller bronchi without occasioning other symptoms than dyspnœa. This early inflammatory irritation will prove, on examination, to interfere with the breathing, mainly from spasmodic action of the bronchial muscles, conjoined with swelling of the mucous membrane itself, and consequent narrowing of the affected tubes, in much the same manner as the wide outlet of the nasal passage is closed in the beginning of a coryza. As soon, therefore, as a secretion bathes the irritated mucous surfaces, though the tubes be largely filled with it, the breathing becomes easier from relaxation of the spasm and reduction of the tumefaction, while the pain likewise is mitigated, except just after a fit of coughing.

Cough is a necessary element in bronchitis, and its sound indicates its character, so that a practised ear will distinguish it as bronchitic without difficulty. With reference to this subject of cough sound, it may be said that all coughs can be divided, according to their sound, into two classes, whose nature and import may be recognized by simply hearing, without necessarily seeing, the patient. The first, or the irritant cough, is the result of direct or reflex irritation alone, and it neither produces expectoration nor is caused by any need for expectoration. It is always composed of separate coughs or hacks, which, however frequent and prolonged, or even though they be severe enough to prevent all sleep, are yet each independent of the other, like the blows of a hammer. The second, or the expectorant cough, on the contrary, is like the running of a chain over a pulley, and though it may be deliberate and slow, yet each cough is connected with the preceding and the following cough, and when once begun it will not stop until some expectoration has occurred. The patient, and all within hearing, are aware that the cough cannot be arrested until something is brought up, though, as in a case of viscid chronic bronchitis, the pellet which is dislodged at last seems an insignificant product for such a strangling time as the sufferer has had of it. To the irritant class belongs the characteristic hack of acute and of chronic pleurisy, and, therefore, also the ominous slight cough of early phthisis. It becomes, however, very loud and barking in hysterical or uterine cough. One of the most violent coughs which I have ever heard was in a lady who proved to have a polypus extruding from the os uteri, and as soon as it was removed this cough, of several years' standing, ceased. Children often have such coughs at night, from intestinal irritation, and the cough of thoracic aneurism is another instance of the kind, and lastly, it is the cough of direct laryngeal irritation, as in croup. This irritant cough, if present at all, is found only in the very first stage of acute bronchitis, and soon gives place to an expectorant cough, which is comparatively slow if moist, and rapid if dry; its conclusion in expectoration being always announced by the last one or two coughs being more or less liquid, and following after a short or very prolonged antecedent series, according to the character of the secretion expectorated.

In acute bronchitis, as just remarked, all cough is in the beginning painful. As each paroxysm ceases, the patient presses his hand against the chest with an expression of distress, and in dread of the next return. After a while he experiences a good deal of soreness between the ribs, with some tenderness on pressure, which, however, must not be confounded with the same symptom in either pleurisy or pleurodynia, for in bronchitis it is located at the attachment of the diaphragm and of the other muscles engaged in the act of coughing, and is but the common result of unwonted muscular exertion.

Cough, therefore, is the chief cause of the patient's discomfort in acute bronchitis, and simply to allay it is the main indication in treatment. Hence the relief will correspond with the ease of expectoration, and this in turn depends upon the character of the secretion. As a rule, the secretion first formed is the most difficult of expectoration, owing to its viscidity. It is composed of a clear, tenacious mucus, much mixed with air from the protracted efforts of coughing, and contains also a few mucous corpuscles, and sometimes streaks of blood. After a time the secretion becomes either more liquid from greater watery admixture, or else more turbid and yellowish, according to the formation of a greater or less quantity of pus. This latter change, in acute bronchitis, is a sign pointing toward recovery, for as the expectoration becomes more purulent it rolls into rounded masses of increasing consistency, but of less frequent formation, until but one or two such accumulations are expectorated in the morning, and then they cease altogether. When that desired termination will occur is uncertain, for the duration of acute bronchitis, like that of other catarrhs, varies indefinitely, as it has no critical periods and ends irregularly

DIAGNOSIS.—Bronchitis is oftenest confounded with pneumonia, especially if the expectoration be bloody. From lobar (croupous) pneumonia we have already indicated some points of difference in the nature and bilateral extent of the pain, in the history usually of an antecedent naso-pharyngeal or laryngeal catarrh, in the absence of a distinct rigor at the beginning, in the moderate rise of temperature, and in the non acceleration of the respiration. Physical exploration of the chest now completes the demonstration. In acute bronchitis there is no dulness on percussion anywhere; if anything, the stroke note is increased in intensity all over the chest, and the vocal fremitus is diminished. In the early "dry" stage auscultation reveals sibilant asthmatic breathing in both lungs, varying constantly in intensity, and usually sufficiently marked to mask or extinguish the vesicular murmur As soon as secretion commences, the whistling sounds give place to sonorous rhonchi produced in the larger tubes, mixed with the characteristic subcrepitant râle proceeding from the lesser bronchi. This râle is not as dry or sharp as the crepitant râle of pneumonia, and specifically differs from it in occurring during both inspiration and expiration, while the pneumonic râle is known by the wholly clear and high pitched expiration which follows it. As the bronchial râle is itself often heard only at the end of inspiration, it should be watched for a number of respirations, and especially after coughing, when its true character will be revealed by its being heard also in expiration; or else it is greatly modified by the cough, while the pneumonic râle can neither be removed nor modified by any respiratory act This distinction also separates the bronchial râle from a pleuritic friction sound, which it often closely resembles, for whereas the friction sound, like the subcrepitant râle, is heard during both inspiration and expiration, it cannot be modified by a deep inspiration or ever coughed away

ETIOLOGY.—Bronchitis is sometimes an accompaniment of other acute diseases, like smallpox, but especially of measles and pertussis, and then it is apt not only to prolong convalescence, but also to cause permanent mischief by generating a proclivity to asthma In typhoid fever, bronchitis is often an early symptom, and it then may be so pronounced as to mask the presence of that disease. The course of the temperature, however, will soon suggest the correct diagnosis, to be soon confirmed by the development of the proper signs of the infection. The bronchitis then usually subsides during the second week. The most significant fact, however, connected with its etiology is that bronchitis occurs only exceptionally as a direct result of excitation of the bronchial mucous membrane itself, by any irritant property or ingredient of the inspired air. The frequency of bronchitis among workers in dusty air, such as millers, rope-makers, etc., does not militate against this statement, for when every such instance is taken account of, it only shows that dusty air can cause bronchitis, as also measles does, but it does not explain why the great majority of cases of bronchitis have not been in dusty air at all Recent researches also prove that bronchitis is not the result of any form of bacterial invasion through the air which enters the lungs. Its occurrence in phthisis can always be attributed to extrabronchial processes and not to primary infection of the mucous membrane, for no demonstration has been more conclusive than that the air in the whole bronchial tract is normally sterile, all germs having been filtered out of it or destroyed during its transit through the nasal passages. This explains, as Lister pointed out, why pneumothorax caused by traumatic injuries of the lungs is not followed by suffocative pleurisy.

On the other hand the one great fact in the etiology of bronchitis, oftener illustrated by experience than any other, is its causation by some chilling of the skin. The peculiarity here is that this chill need be but very partial and often of cutaneous areas quite remote from the lungs. Sitting with wet feet in a cool room will induce a severe attack of the complaint much more commonly than the breathing of any kind of air, however cold or hot or dry or moist it be. So a cold draught upon the nape of the neck, especially if the skin be perspiring, always entails a risk, even in the healthiest persons, of an attack of bronchitis or of a catarrh of some other part of the respiratory tract. Such effects of surface chilling, however, are best illustrations of that most common disorder which is denominated "catching cold." Considering how frequent this derangement is, and how often it leads to severe or fatal internal derangements, it is strange that so little progress has been made in the investigation of the pathology of chill. It seems to me that we must look for its most probable explanation in the sudden local closing of the arterial circulation of an internal part by reflex vaso-motor irritation from the surface. Experiments on the kidney have shown that clamping the renal artery for only twenty minutes causes such damage to the renal secreting cells that albuminuria lasting two weeks may be set up by this brief arrest of the arterial flow. Now it is a general law of vaso-motor association that the cutaneous nerves are always in relation with the vascular nerves of the internal organs under that part of the skin, so that the same kind of vascular impression, whether stimulant or sedative, to the surface nerves is reflected to the nerves controlling the circulation of the deeper parts. It is in accordance with this law that cold suddenly applied to the abdomen will contract the internal arteries and check a post-partum hemorrhage, or a warm poultice to the chest soothe the pain of a pleurisy, etc. But besides this general law, there are many examples of special vaso-motor associations between distant parts. Thus the nerves of the feet are closely associated with the vaso-motor nerves controlling the circulation of the pelvic viscera, so that cold to the feet will check menstruation, and dry heat thus is one of the most reliable emmenogogues. Whoever has an irritable stricture of the urethra should not get his feet wet. The nerves of the nape of the neck also have wide relations of the same kind. Hence it seems reasonable to surmise that the process of "catching cold" is caused by the irritant surface impression of a chill reflected by some customary nervous association so as to shut off the arterial blood from some internal tract or viscus sufficient to inflict an injury there comparable to the injury to the kidney cells in the experiment above alluded to, and the subsequent inflammatory development is the expression of the local reaction to that injury.

Pathology.—Acute catarrh of the primary and medium-sized bronchi is rarely a dangerous complaint, and, if we consider its frequent occurrence, it is the least serious of any of the pectoral affections, particularly when compared either with laryngitis on the one side, or with catarrh of the smaller bronchi on the other. A post-mortem examination, if it could be had, of an adult who at the time of his death was suffering from a severe chest cold such as we are now considering, would reveal very little, if any, departure from health, owing to the removal of all traces of hyperæmia by the emptying action of the elastic fibres which line the tubes. We can best judge of the morbid changes by observing the traces of an incipient bronchitis in those who have died from other diseases. The first step is a hyperæmia of the vessels of the inner fibrous coat, which become swollen and softened and infiltrated with lymph cells, accompanied by œdema of the basement membrane, from which are detached numerous ciliated columnar epithelial cells, while new cells from the deeper layer of the epithelium are successively cast off mixed with leucocytes from the congested blood-vessels

Treatment.—There is no disease in this country which so often brings patients for a prescription as this form of bronchitis. This is due not only to its own exceptional frequency, and the discomfort which it occasions, but also to the just dread which a visitation of cough causes among most persons. Ordinarily, of course, they are mistaken in supposing that phthisis means a neglected cough, and therefore that "it will never do to let a cough run"; but there is cause enough always for shortening every bronchial catarrh in order to prevent the formation of a habit of the kind, which is common to all inflammations of the mucous membranes. The aim, therefore, should always be to prevent an acute bronchitis from becoming chronic, either actually or potentially, and hence, in this complaint, the less trust in nature, or in spontaneous recovery, the better. When called to a patient who has not passed beyond the condition of hyperæmia and swelling (generally termed "the dry stage" of bronchitis), the physician's first duty should be to induce secretion as quickly as possible. If the patient be not too young, or too old, or too debilitated, much the most effectual proceeding to secure this end is to dissolve a grain of tartar emetic in a teacup of water, and tell him to take a teaspoonful of this every ten minutes. As soon as he begins to be slightly nauseated by it his pain rapidly subsides, owing to the anæsthetic effect of antimony; the spasm of the bronchial tubes relaxes, and soon a watery secretion flows and expectoration begins. It is not necessary to carry the administration of the antimonial to the point of producing emesis, for it cannot abort the inflammation, and we have much better remedies for the succeeding stages of the complaint.

As we have remarked before, cough is the one symptom to combat in acute bronchitis (not bronchiolitis), for it is apt to do a great deal more than produce expectoration. In acute (not chronic) inflammations the first indication is to secure quietude of the inflamed part, and every act of cough is an infringement of this rule. The severe pain which each paroxysm causes proves the mischief which it occasions, and hence, as some coughing must occur in order to remove the secretion formed, the purpose should be to render the secretion capable of removal by as few acts of coughing as possible, and then to suppress the superfluous remainder. Hence the more watery and the less adhesive the mucus can be made, and the less reflex irritation there be from the inflamed part, the sooner will the bronchitis subside. To fulfil the first indication, namely, that of inducing a watery flux, the most efficacious remedies are oils. To prove this, one need introduce only a few drops of sweet oil into his nose and note the flow which will speedily follow. The action of castor oil on the intestinal mucous membrane is another illustration of the action of oils, and we may mention in passing that castor oil on this principle is a dangerous cathartic to give to infants with bronchitis, from its tendency to fill their small tubes with too much secretion. Now certain oils have a particular affinity for the bronchial mucous membrane, and hence have a right to be classed among expectorants, and one oil, the oleum lini, or linseed oil, has this property to such a remarkable degree that it is one of the very best means at our disposal for painful bronchial coughs of every kind, including phthisical bronchitis. I was first led to use it from the fact that domestic experience had long shown the soothing effects of flaxseed tea in bronchitis, and I feel certain now that no other remedy is so effective as the oil itself in active inflammatory states of the bronchial mucous membrane. To insure a good emulsion it is better to make it in some quantity, thus· Irish moss, ℥ i., boil in water for an hour and strain, making O iij., then add ol. lini ℥ xv., ol. gaultheriæ, ol. cassiæ, āā ʒ ij., glycerini ℥ v., syr. simpl. ℥ x., ac. hydrocyanici dil. ♏ clx. A six-ounce cough mixture of this emulsion may then be made by the addition of a grain of morphine and a drachm and a half of chloral, of which the dose for an adult is a tablespoonful taken an hour after meals. A firm in Danbury, Conn., has made a proprietary article out of this emulsion, and I am told sells it widely under the name of Linolin.

When the bronchitis develops in the course of a descending catarrh from the pharynx and larynx, and especially in those with laryngeal pain, the action of full doses of aconite is very beneficial. A combination of tincture of aconite and camphorated tincture of opium with spirit of nitrous ether and syrup of senega may be employed for the same purpose as the linseed-oil emulsion, especially in patients who dislike all oily mixtures. Iodide of potassium, in doses of four grains, also comes under the head of liquefying expectorants, and to a less degree the carbonate of ammonia.

After a few days, in many persons the secretion often increases, especially in those who have had repeated attacks, until it becomes a very inconvenient and obstinate bronchial flux. Here the indication is for a combination which will start secretion and at the same time not allow it to become too viscid. Dr. C. J. B. Williams' favorite prescription for phthisical bronchitis, with abundant expectoration, is useful under these circumstances; it contains nitric acid, iodide of potassium, syrup of senega, and balsam of tolu. The addition of belladonna renders it still more certain in diminishing the flux.

The use of hot drinks on going to bed, especially those containing alcohol, for the purpose of getting up a perspiration, should be reprobated. Alcohol is uniformly mischievous in all catarrhs, acute or chronic, and the benefit of perspiration can be much better obtained by a Dover's powder and aconite taken while the patient wraps himself in an extra covering and sits with his feet to a fire without moving from it for some hours until he can go directly to bed. This, then, should not be too warm, for a nocturnal perspiration is always risky.

Counter-irritation is justly reputed among the laity as of much service in bronchitis. At the very start, a sinapism to the chest, especially if made large and applied for only a short time, may cut an attack short. After the second day it is rarely of any use, and furthermore it should never be applied in measles, as the action of mustard on the skin when inflamed by measles is apt to be very severe, and I have known of two fatal cases, in children, of gangrene of the surface of the chest from the ignorant use of mustard in this exanthem. Stimulating embrocations, however, such as the soap liniment, with turpentine and aqua ammoniæ, are useful both in the onset and decline of bronchitis, if only to lessen the cutaneous hyperæsthesia or sensitiveness to draughts, which accompanies all severe catarrhs of the respiratory mucous membrane.

2. Acute Bronchiolitis, or Capillary Bronchitis.—This formidable disease, with a mortality of from thirty-five to fifty per cent. of all attacked, is much more than a simple bronchitis, for the accompanying inflammation not only extends beyond the terminal bronchi into the alveoli, but also affects the peribronchial tissue, and may even involve the pleura. The affected tubes lie far within the substance of the lung, and, having lost all cartilage, they ramify as small thin membranous channels between textures rich in blood-vessels and in meshes of connective tissue. An inflammation reaching to them, therefore, may thus give rise, by involving the surrounding structures, to both acute and chronic changes of greater constitutional effect than in the case of any simple mucous catarrh. A pretty sure indication of this fact is found in the sudden rise of temperature which is observed whenever an acute bronchitis is passing into a bronchiolitis, for this proves that a profounder reaction has occurred than pertains to the course of a mucous-membrane inflammation. It is difficult, indeed, to draw a sufficiently marked distinction between the lesions which are apt to arise from the extension of a bronchiolitis and the phenomena of so-called catarrhal pneumonia. The term catarrhal has been objected to as applicable to a pneumonia, because the air cells cannot be said to contain mucous membrane, but the significance is obvious enough as indicating a pulmonary consolidation arising in a pneumonic process whose origin really comes from the bronchial tubes. While, therefore, capillary bronchitis as such is a frequent disease of early childhood, and often proceeds to a fatal termination without general implication of lung tissue, in adults pneumonia, consecutive to diffuse bronchitis, is a common affection, especially in the aged or feeble, or when supervening upon a chronic bronchitis. In these patients greater areas of consolidation are found in both lungs than is common in children; but it is difficult to demonstrate any specific difference in the morbid processes themselves, as the gradations between the two are of every degree, the smaller bronchi being almost exclusively affected in some adults, and pneumonic consolidation being the most pronounced lesion in many children.

The main reason for the gravity of capillary bronchitis is to be found in the comparative weakness of the bronchial muscles of patients affected with this disease. This cause pertains equally to the affection in children and in the aged. The muscular coat begins in the trachea and in the primary bronchi, where it joins together the free ends of the incomplete rings or **C**-shaped cartilages, and can thus on occasion contract the calibre of even these larger tubes. As the bronchi further divide, the muscular layer relatively increases, becoming more or less a circular coat, until it ends at the alveolar passages as a thick bundle of annular muscle fibre cells, forming a kind of sphincter (Rindfleisch). Upon the muscular layer lies the thick layer of longitudinal yellow elastic fibres which are continued on into the texture of the air vesicles themselves. Now, as the one function of muscle is to produce movement, it is plain that these muscles, acting upon the recoil of the elastic fibres at the moment when the external expiratory muscles are driving the air through the tubes in coughing, could, by a quick contraction upon the current of air, greatly assist the propulsion of fluids toward the larynx.

In children the bronchial muscles are not only relatively of much less development and power in proportion to their youth, but they are equally weak in the muscular apparatus of the throat and in the expiratory muscles of the chest, the latter having the further disadvantage of the yielding nature of the chest walls to which they are attached. Young children, therefore, cannot clear even their throats of mucus, but rather swallow that which is brought up, and in proportion to their debility, whether due to age or to imperfect development, will the danger increase of suffocative accumulation in their air tubes. In the aged, on the other hand, bronchial palsy, consecutive to chronic bronchitis, is the commonest condition which leads to a fatal complication.

Capillary bronchitis affects children more commonly in the first year of life; the frequency then diminishes progressively up to the third or fourth year; and, finally, the disease may develop from any of the common causes of acute catarrh of the respiratory tract. It is, therefore, of exceptional severity in whooping-cough, and ranks as the commonest cause of death in measles. It occurs also during the winter months, as one of the complications of dentition. At other times it develops upon an ordinary cold, which has begun with sneezing, and, after setting up a coryza, goes on to develop laryngo-tracheal symptoms for several days, until finally symptoms of a more pronounced constitutional kind begin to manifest themselves. The child becomes heavy and drowsy, with longer and more severe paroxysms of coughing, followed by dyspnœa, which is evidently due to paroxysmal spasmodic action in the bronchial tubes. After a time the nostrils begin to be permanently in action, a constant restlessness sets in, the respirations become accelerated, the head grows hot, and the face is deeply reddened during the attacks of coughing, which, though very hard, yet do not bring up much secretion. The cough has a peculiar whistling character, quite different from the brassy sound of croup, and a distinct wheeze is audible in many cases without applying the ear to the chest. The thermometer now shows that a rising fever is on hand, for a temperature from 102° to 103° F. in a child with a cough should always cause solicitude. Percussion at this stage does not afford much information, but later on it may reveal localized areas of dulness, especially in the infrascapular and subaxillary spaces. Auscultation sometimes affords nothing but highly puerile respiration, but oftener a great number of high-pitched, fine, sibilant sounds are heard accompanying both inspiration and expiration. The presence of areas of consolidation is sometimes made out by localized exaggeration of both breathing and voice sounds, especially after a fit of coughing. It should be remembered that a child's chest, being so much smaller relatively than an adult's, is proportionately more resonant, and often transmits sounds of all kinds over to the side opposite to that on which they originated.

Meantime, with the progress of the case, both pulse and respiration grow more and more frequent. The child can nurse or drink only with a short, hurried effort, and, as the respiratory obstacle increases, its chest begins to show signs of disordered breathing which are very significant. The lower ribs and the epigastrium sink in during inspiration, indicating widespread obstacles to the ingress of air. On the other hand, the residual air in the lungs both increases and becomes rarefied, so that the supra- and infra-clavicular spaces become distended and the upper part of the chest seems scarcely to move with the breathing. As the case progresses the body temperature varies from 102° or 103° in the morning, to 104°, 105° F., or even more, in the evening. The pulse rises from 150 to 180 or 200, and the respirations to 50, 80, or 100 per minute, while the constant tossings of the patient and its expression of terror too plainly indicate the dread of approaching suffocation. As might be expected from the lack of air, its cry is low, plaintive, and short. If relief does not come, signs of exhaustion, from the excessive labor of the breathing, begin to appear; the lips first turn blue, the face and surface generally become cool, pale, and livid, the pulse grows thready, the cough ceases, and the stupor of carbonic-acid poisoning grows deeper until death closes the scene, with or without slight convulsions.

The duration of the disease is not very definite. In favorable cases it may last ten days and then occupy a week in recovery, with increased but more expectorant coughing at first, and with a plain increase of inspiratory power. In others who recover, the febrile stage may yet last for from three to four weeks. In a certain proportion of cases the disease passes into a fibroid alteration of extensive regions in one or in both lungs. As the inflammation then becomes chronic the peribronchial connective tissue greatly hypertophies, causing more or less obliteration of the air cells, and, finally, adhesions of the thickened pleura to the chest walls. Great bronchial dilatation is then apt to follow in the consolidated parts, surrounded by emphysematous lobules, and a constant secretion of muco-purulent sputa is thrown off. These symptoms, combined with the great emaciation of the patient, seem to leave nothing wanting for the diagnosis of tuberculous phthisis. Often, however, so much improvement of a permanent kind occurs, if the patient survives for a few years, that the prognosis need not be as hopeless as the same degree of wasting would imply in an adult.

The post-mortem appearances, after capillary bronchitis, vary according to the participation of the lungs in the inflammation. If the case has been chiefly bronchitic, the lungs do not collapse when the chest is opened, but may even bulge out as if they had been compressed by the ribs. This pseudo-emphysema is caused by the occlusion of the bronchi by mucus and other products of the inflammatory process. Commonly, however, the surface of the lungs is irregular from alternate collapsed and overdistended lobules, according as the valve-like action of the secretion in the tubules had allowed more air to pass during inspiration or more during expiration; the condition of overdistention being produced when less air could be forced past the obstacle during expiration than during inspiration, and a condition of collapse being produced when the reverse was true. The areas of pneumonic consolidation, on the other hand, present just the same appearances and changes that occur in cases in which a bronchus has been plugged by a foreign body. The inflammatory process then involves the whole parenchyma of the lobule, both of the air vesicles and interstitial tissue, so that instead of complete resolution following as in croupous pneumonia, fibrous or caseous changes are apt to remain. The bronchi, which are universally stuffed with mucus, pus, epithelial cells, etc., show very generally a reddish and swollen mucous membrane, this condition extending even to the primary bronchi, if not to the trachea; in which respect the appearances presented in this disease contrast strongly with those observed in simple bronchitis.

Treatment.—We scarcely need say that the treatment of capillary bronchitis should be prompt and decisive, and hence according to clearly defined purposes. As soon as the thermometric rise and the other symptoms indicate the threatening approach, the aim should be to shorten the acute stage of the inflammation as quickly as possible. For this purpose aconite is the best medicine, and should be given with the set determination to make the patient feel it. Every two hours doses of one, two, or three drops of the tincture of the root, in a solution of citrate of potash, should be given until the pulse falls in frequency and "excitement." Should the pulse grow weak or intermittent under this course, the use of stimulants will soon show that the acute inflammation is itself a guard against too great doses of aconite, for only a few teaspoonfuls of brandy will be enough soon to counteract the depression of aconite, which in a normal state, or in a chronic disease, would continue for hours. There is no remedy which can do as much as aconite just at this juncture; later on, it is mischievous, but at the beginning it is much the best antipyretic and antiphlogistic that can be employed, because of its specific effect in lessening the initial engorgement of the respiratory mucous membrane when acutely inflamed. We see this exemplified in tonsillitis, in which disease, when given in full dose, it often cuts short the otherwise tedious course of the affection toward suppuration; and a like power to prevent the congestion and the formation of muco-pus may be fairly attributable to it in bronchitis, while its anæsthetic effect is beneficial both to relieve the pain and to control the consequent asthmatic spasm of the bronchioles. We do not have the same reason to fear cardiac weakness in capillary bronchitis of children as in the aged, for the heart of the child is relatively stronger than that of the adult, at least as regards the right side, which has about the same thickness in early life as the left.

When sibilant râles begin, we should add, and continue systematically to give, the tincture of belladonna in full doses, combined with half a drachm to two drachms of the spirit of nitrous ether, in sweetened water or milk, every three or four hours. This combination is not to be omitted until convalescence begins; for while the aconite may be dropped as soon as signs of exhaustion appear, or if the temperature is relatively low, the belladonna and nitre should be faithfully persisted in as respiratory stimulants, to strengthen the function most imperilled, and also to lessen the complication of bronchial spasm.

Then when moist râles, a recurrent dyspnœa, and exciting hard cough come on, we have a plain indication to try to expel retained secretions. Here a single emetic, administered every twelve hours, is of true service. Some writers condemn emetics on the ground of failure, in their experience, to afford relief by their use. If wrongly administered, emetics are not remedial in bronchitis, but dangerous instead; still, that is no reason for neglecting the most efficient method of expelling mucus in children. Vomiting is both natural and easy to children, while expectoration is much the reverse, and no one who has witnessed the great relief following upon the effective action of the abdominal muscles after an emetic, in dislodging a quantity of mucus where the hardest coughing of children had failed to produce any effect, will doubt that emetics can do great good in the hands of those who know how to use them. In the present instance, neither antimony, ipecacuanha, nor apomorphine should be employed, because they excite too much bronchial secretion, and hence when they do act they give but the most evanescent relief. Often also they fail to act as emetics at all, whereupon their effect is bad, for nothing is so calculated to fill the tubules with liquid as a prolonged nausea. Instead of these emetics we would recommend, first, the turpeth mineral, or yellow sulphate of mercury, in doses of two to five grains; or, second, the sulphate of copper, half a grain; or, third, the sulphate of zinc, in a dose of five grains combined with the same amount of powdered alum, in a tablespoonful of water. None of these emetics operates except in the one way of irritating the nervous association with the gastric nerves to expel a gastric irritant. The heart is not depressed by them, nor the bronchial mucous membrane rendered œdematous; and moreover, if emesis does not follow very speedily after their administration, they do not act at all, and may safely be left alone, as far as the bronchial membrane is concerned, if a second dose has not been followed in ten minutes by vomiting. The case, then, is not one in which emesis should receive further trial, at least for another twelve hours. A more frequent administration of emetics than once in twelve hours is useless.

When the struggle for breath once begins in deadly earnest, the indications change to the two purposes of supplying oxygen and of sustaining the patient in the dread struggle. Why should the necessary restlessness of the patient be now smothered by opium?

It is difficult to see any reason for the employment of this drug, from first to last, in this critical disease, other than that of securing the deceptive quiet which this most effective paralyzer of respiration may occasion in bronchitis preparatory to a quiet forever permanent. A much better relief to the distress and cough is afforded by a mixture of chloral and camphor, to which a very small quantity of an opiate is added, as in the following: ℞ Chloral, ʒ i.; Magend. sol. of morphia, ♏ x.; syr. simpl., ℥ ss.; aq. camphoræ, ad ℥ iij. M. Sig.: Teaspoonful in sweetened milk. In the mean time, if pure oxygen gas can be procured for inhalation, we can speak very favorably of its aid in battling for life in these cases, both by assisting the breathing and by strengthening the heart. On this account, the air of the room in the immediate neighborhood of the patient should be constantly renewed, while at the same time any chilliness noticeable in it should be counteracted by artificial heat, tempered with steam. Inhalations of steam vapor are not called for, if laryngitis is absent, inasmuch as the necessary measures for steaming may interfere with the free supply of oxygen.

The indications to sustain the patient's powers now call for the most fearless use of alcoholic stimulants. Of all such preparations brandy does best for children, and may be given to them with or without milk, generally best in some hot liquid; in the suffocative stage of bronchitis it may be given continuously in doses of one, two, three, or even four drachms every hour It will be noted, now, that cardiac stimulants are of the most service, and hence *external* irritants will often greatly aid the other measures adopted. While an external covering is of great value in the first onset, and then the more soothing its effect the better, exciting ones are the effective means at the last. We would recommend, therefore, a jacket of wadding for the chest, covered with oiled silk, during the early stage of the complaint, to be followed later on by baths in hot mustard water. The latter should be taken once in six hours, and should be continued each time until the skin is reddened; and occasionally a cloth wrung out of a hot infusion of capsicum, ʒ i. to the pint, should be applied to the chest for from five to ten minutes, and then the wadding jacket should be put on again as before. Another good point in practice is to give an infant who is struggling for breath something hot to swallow every few minutes. Half a teaspoonful of hot milk and lime water, or some such excitant of the act of deglutition, powerfully helps expectoration, as I have had frequent occasion to note, as well as relaxes bronchial spasm. Kroenecker found that every act of deglutition acts as a cardiac stimulant, and raises the blood pressure.

Many of the favorite remedies employed by different writers in the treatment of broncho-pneumonia can be mentioned only briefly, because, having tried them, we are too uncertain of their beneficial effects to prescribe them hereafter in cases of our own. First, ammonia, as a cardiac stimulant and expectorant, is largely employed, and in older children may be beneficial, as it certainly is in the pneumonia of adults. The difficulty with it in little patients is the irritation which its administration, however disguised, causes in them compared with adults, for it excites both coughing and crying. Quinine is given in pulmonary inflammations with the same regularity at present as blood-letting was resorted to half a century ago, and with no better reason. Aconite is a far more certain antipyretic than quinine in this complaint; while the depression produced by quinine upon the heart in children is decidedly more permanent than that of aconite, and at the same time there are no compensations to warrant its administration.

3. Chronic Bronchitis.—This common disease unlike the preceding, is usually a complaint of middle or of declining life, and fully illustrates in its course the inveteracy and proneness to relapse of all chronic disorders of mucous membranes. Although the structural changes which chronic bronchitis induces may become very extensive and may involve secondarily the most distant parts of the body, producing changes in the abdominal viscera and in the entire circulatory system, yet it always remains essentially a local and not a constitutional disease. This is a matter of practical importance to the physician, and is well shown by a comparison between chronic bronchitis and pulmonary phthisis, the disease with which it is most apt to be confounded, on account of the most prominent symptoms of each being cough and profuse expectoration. Thus, a significant difference meets us at the outset in the personal appearance of patients, even in the advanced stages of these two complaints, and one which indicates a difference of both nature and origin. Phthisis from the beginning is a wasting constitutional disease, frequently manifesting a loss of bulk in every structure which is related in any way to the function of respiration, before any respiratory changes can be detected, except perhaps quickened breathing. The early contraction or want of action of the lung apices produces a characteristic elongation of the neck from sinking down of the clavicles, which causes the patient to carry his chin forward beyond the line of the chest and abdomen. The muscles of the neck also appear thin and ribbon-like, although the imperfect respiration causes these auxiliary muscles to stand out more plainly under the skin in forced inspiration than they do in health. Following upon this change in the neck, there is a peculiar retraction of the cheek toward the angle of the jaw, while the early emaciation appears in the pinched features, the sharply defined nostrils and ears, and the too clear conjunctiva, which shows the sclerotic through it like a polished glass ball. The hands, which in all cases show emaciation better than the face, look bony, and have a bird-claw contour, from wasting of both dorsal and palmar muscles; while the bones generally, like the muscles, have a tendency to be narrow and thin. The skin of the consumptive is of silky smoothness, with long blue veins, and, except at the onset of the daily fever, is moist as well as soft. In contrast to all these characters, a case of severe bronchitis presents us with a round and much distended chest in the very region where it is flattened or sunk in phthisis. The clavicles, therefore, are elevated instead of depressed, and the neck is directly shortened. The chin, instead of being carried forward, is drawn back, and the neck muscles are large, broad, and massive, being much hypertrophied by the labor which they are called upon to undergo in lifting the chest, because in chronic bronchitis the vertical movement of the chest walls is increased in proportion as the lateral and the antero-posterior movements are decreased. Chronic bronchitis, moreover, being a non-

febrile disease, does not cause atrophy of the muscles, and hence the powerful array which may be seen under the skin of the neck whenever coughing begins. Owing to the same cause, the supraclavicular depression, which is nearly obliterated in phthisis, is much deepened in bronchitis, in some instances sufficiently so to admit of several fingers being laid in the cavity; and if emphysema also be present, quite notable tumors rise from the bottom of the depression during coughing, which are caused by the distended subclavian and innominate veins. The face is turgid, the complexion is often suffused, the nose and ears are thickened, the conjunctiva has an œdematous appearance and is traversed by tortuous veins, while the skin, particularly if emphysema and consecutive chronic hepatic congestion be present, is dry and leathery, and can be drawn into wide, non-elastic folds. Everywhere under this thickened skin the veins appear enlarged, tortuous, and dark-colored.

Symptomatology.—The most common history of a chronic bronchitis is that the patient was at first subject to frequent attacks of acute bronchitis, especially in the last weeks of winter or in a belated spring. His cough, he tells us, hung on by his taking a fresh cold every time he went out or the weather changed; and he tells his story correctly, because he had reached that state of susceptibility to relapse on slight provocations which is the penalty of leaving an inflammation of a mucous membrane only partially healed. Just as an old gleet will return after some trifling error of diet, so does a bronchitis revisit its victims upon the slightest chill or exposure to a draught of air. So soon, however, as milder weather comes, when the skin is kept in a state of gentle perspiration, the bronchitis is displaced and the cough ceases until the chilly season comes round again, when the same experience is repeated, with an increase, each year, of the severity or the duration, or both, of the bronchitic attacks. After an indefinite length of time, according to the individual case, the cough becomes permanent, and merely decreases in severity during the favorable season. But meantime it is worthy of note that not until long after the bronchitis has become continuous, so to speak, does the patient's general health seem to suffer materially; for, in great contrast with a true consumptive after the same lapse of time, he loses but little in flesh or color, and in summer often seems quite well. Prolonged cough, however, at last begins to tell, and the first sign of injury is usually breathlessness upon muscular exertion. This is mainly due at first to weakening of the air vesicles by overstrain, and may be entirely recovered from. Another complication is soon added, which in some individuals comes on much earlier, namely, asthmatic breathing. This is a most unwelcome addition to a bronchitis, for it rarely parts company with it thereafter, and meantime greatly increases the textural mischief wrought by the primary disease. In time dyspnœa becomes habitual, whether the patient has been coughing or not, and ere long signs of embarrassment of the pulmonary circulation develop from weakness of the right ventricle, the far-reaching results of which are now to be detailed.

The cough of chronic bronchitis is varied in character according to the quantity and quality of the secretions expectorated. One kind has been graphically termed "dry" catarrh, from the small amount but great viscidity of the discharge. This secretion can scarcely be propelled along the bronchial walls, and when it reaches the bifurcation of the trachea the most violent and rapid paroxysms of coughing commence, in which reflex laryngeal spasm participates, causing the sound to become like a whistling squeak. The patient has to use every expiratory muscle to the utmost, and doubles himself up with the effort, while his face grows purple and his eyes and nostrils water, until the tenacious streak of mucus is finally dislodged with much gagging or even vomiting. This severe coughing naturally produces injury of the small bronchi and of the air vesicles from mere mechanical violence, so that emphysema is more likely to occur in this than in any other form of bronchitis.

The other and more common form is that in which the secretion is abundant and liquid. The amount and consistency of this, however, vary greatly. Some are able to get rid of the most of it at one fit of coughing, and then remain measurably free for hours; others have a steady flux, which rarely allows them any prolonged intermission in their efforts at expectoration. This bronchorrhœa is apt to be particularly harassing at night, and is the torment of many old persons, who can rarely lie down after midnight. In the majority of cases this condition is dependent upon cardiac weakness, and hence, even in the best summer weather, when the cough is much mitigated although still moist, râles will be found to prevail at the bases of both lungs posteriorly.

The character of the expectoration of these patients varies also in other respects. In some the watery flow is markedly predominant, and, when expectorated into a vessel containing water, the muco-pus floats in irregular masses on the surface, owing to the air which is entangled in its meshes. In others pus itself is raised in great quantities and in rounded masses. In still other cases, however, which are usually of long standing, the expectoration is very liquid in parts, and of a brownish tinge ("prune juice"), with masses of fetid, purulent, and rather adhesive secretion which sinks to the bottom of the cup. This fœtor has been interpreted as a sign of prolonged retention in some cavity on the way, and therefore an evidence of sacculated enlargement of the bronchi. While this is doubtless true of most cases, yet it is not so of all, and the fetid secretion may then be caused by some special putrefactive ferment in the bronchial wall itself. This is rendered possible by the curious fact that the fœtor is so much greater in many instances than is found in the largest phthisical vomicæ, and, moreover, is so much less easy to disinfect. It is sometimes difficult to distinguish it from the odor of gangrene of the lungs, and the diagnosis has to be based upon the different antecedent history and subsequent course. The breath also often remains offensive after the expectoration has chiefly lost its odor; at other times, the fœtor comes and goes without any assignable reason. Neither is it necessarily a dangerous complication, for the worst case, as regards odor, that I have ever seen was in a young man who had it for several years, while his general appearance continued extremely good.

Acute Broncho-Pneumonia Supervening upon Chronic Bronchitis.—Chronic bronchitis may terminate rather suddenly by the supervention of an acute diffuse bronchitis with consecutive pneumonia. There is reason to fear an access of this kind if a patient, who has suffered from this complaint for a long time, begins to feel chilly and feverish. A development of fever in a comparatively non-febrile complaint like this is always of serious significance, as it is in the bronchitis of children. The cough becomes much more severe and exhausting, and the implication of the smaller bronchi is rendered probable by the characteristic appearance in the sputa of long threads of mucus hanging down from the larger masses as they float in the more liquid portion. These mucus-strings are derived from the smaller bronchi, which they nearly occlude until expelled by great effort, and, if the patient's strength fails, the symptoms rapidly assume a grave constitutional character. The cough grows more and more ineffectual, the fever increases, and a low delirium sets in, with much subsultus tendinum, a dry tongue, and often free sweating. It is an unfavorable sign when the patient no longer attempts to sit up, or to turn on his side, or when the cough ceases. Physical exploration shows the ordinary signs of broncho-pneumonia, and while the prognosis is always serious, it is worst when among the antecedents there has been a weak, dilated heart, emphysema, bronchiectasis, or old age.

PATHOLOGICAL ANATOMY.—There is no disease the general course of which is better explained by its morbid anatomy than chronic bronchitis. The changes that are found after death are so manifestly explanatory of the ante-mortem history that both the symptoms and the sequelæ of chronic bronchitis are best understood by keeping in mind the organic alterations which produce them. After chronic bronchitis, there is usually found considerable discoloration of the lining mucous membrane of the bronchi, either brownish and generally diffused, especially if the case has been complicated by cardiac disorder, or else in scattered red points, which increase to patches about the bifurcation of each bronchus. Of greater significance, however, than these vascular signs is the hypertrophy of the mucous membrane itself, which shows also a very irregular surface from still greater thickening of the subjacent longitudinal elastic fibres and hypertrophy of the muscular coat. Like all hypertrophied unstriped muscular fibre, the muscles are frequently found in a state of fatty degeneration, and evidently possess but little of their normal contractile power. This is especially the case in the sodden tissues found in bronchorrhœa. The bronchi themselves appear to be passively dilated, and on section of the lung multitudes of the tubules are found to resemble the primary divisions in calibre, until further examination shows that they spring from smaller bronchi than themselves. The secretion found differs according to the form of the disease in life, being highly purulent and tenacious in the so-called dry catarrh, and filling all the smaller divisions with watery mucus in those characterized by more flux. It is, however, as we proceed further into the adjoining tissues that the most instructive lesions are found. Emphysema, as might be expected, is always present to a lesser or greater extent, sometimes occupying mainly the edges of the lung, at other times spreading out in every direction, interspersed with bands of fibrous tissue which strikingly assimilate the appearance of the viscus to that of a case of fibroid phthisis. The recent demonstration, however, of the specific nature of tuberculosis and its dependence upon a parasitic organism, renders it as incorrect to speak of a bronchitis turning into phthisis as of a urethritis changing into syphilis; while, of course, it is not denied that a peribronchial inflammation, due originally to a chronic bronchitis, may afford a good nidus for the reception and development of the phthisical virus. The common accompaniment of fibroid thickening from any cause, namely, the development of bronchiectatic cavities, leads to a still further resemblance to phthisis, and one which in some cases makes it difficult to settle the diagnosis without a full history of the beginning and course of the disease.

Besides the production of emphysema, one of the common results of chronic bronchitis is a slow implication of the surrounding connective tissue, which, as we have seen in capillary bronchitis, occurs with great rapidity. Peribronchitis is distinguished by a tendency to pass from lobule to lobule outward, until it involves the pleura and produces thickening of that membrane. This effect has been ascribed by some to an extension of the inflammatory changes along the nutrient channels, which belong to the bronchial arterial system, rather than to those of the pulmonary vessels. One result is a great fettering of the expansion of the lungs in this complaint, so that on inspection of old cases we often find the lower ribs contracted, and either wholly immovable or else falling in with each inspiration, the only well-marked thoracic movement being vertical, and carried on mainly by the neck and shoulder muscles.

The results of such changes upon the circulation now remain to be briefly considered. It is inevitable that the right ventricle should sooner or later become enlarged and dilated by the prolonged obstruction caused by the disease in the pulmonary circulation. Universal venous congestion, therefore, is a common result of a bronchitis which has lasted long enough to embarrass the outflow into the lungs. Brown induration of the liver, with gastro-intestinal derangement, follows. The marasmus of chronic hepatic disease shows itself over the body in the dry, thickened, and wrinkled skin, in general arterial rigidity and muscular atrophy, and in a tendency to interstitial increase of connective tissue throughout all the organs. Hence old bronchitic cases, instead of resembling the soft, white, emaciated forms of the phthisical, much oftener look like the withered and dusky sufferers from cirrhosis of the liver. The portal congestion induced by the hepatic obstruction produces gastric catarrh, constipation, and hemorrhoids, and later the kidneys partake in the venous stasis, so that the urine becomes scanty and high-colored. As the return current of blood becomes more and more impeded, ascending œdema from the feet develops on to general anasarca, in the usual fashion characteristic of cardiac dropsies.

Etiology.—The causation of chronic bronchitis is dependent, in the majority of cases, upon recurrent acute attacks, as just described. The original proclivity to such attacks, however, undoubtedly varies in nature in different cases. Some persons seem to have a hereditary diathetic tendency to bronchial catarrh, beginning generally with a chronic sensitiveness of the pharynx. These cases are characterized by imperfect circulation of the feet. There are a number of individuals, however, who are prone to chronic hyperæmia of all mucous membranes, which shows itself in swollen and reddened eyelids, and in chronic nasal, pharyngeal, or aural inflammations; they also have disorders of the abdominal viscera, accompanied by sediments in the urine, etc., all of which ailments seem connected with some irritant in the blood from malassimilation; and when persons of this class contract a bronchitis they seem never to get rid of it. That the gouty diathesis disposes to chronic bronchitis is well known, but so also do all sclerosing disorders, such as chronic alcoholism, with or without cirrhotic changes in liver or kidneys, and particularly when arterial degeneration is added. Lastly, mitral valvular disease leads to bronchial stasis and flux, the more so on account of the peculiarity of the bronchial arteries which communicate freely not only with the general systemic veins, but also with the pulmonary veins—vessels, therefore, which lie in the direct track of a mitral obstruction.

Diagnosis.—The diagnosis of chronic bronchitis is difficult only when the discrimination has to be made between it and fibroid phthisis or chronic pleurisy. The points in which it differs from phthisis have already been reviewed. Fibroid changes in the lung, however consecutive to chronic pleuritic adhesions, are very analogous to those in many cases of chronic bronchitis; but the initial history of the former is very different, as it begins with pleuritic pains and continues frequently to repeat this symptom to the last. Similar pains also characterize the course of fibroid phthisis to a much greater degree than they do bronchitis. Physical exploration of the chest is not very satisfactory in chronic bronchitis, from the too great number of signs. Aside from a few cases with pleuritic adhesions, the sounds obtained by percussion are usually not much altered from the normal except in the direction of increased resonance. Auscultation, however, meets with nearly every sound which can be generated in the chest. When we reflect that in a well-marked old case we may have a much greater than the usual number of large tubes, filled in varying degree with various kinds of secretions, in close proximity to asthmatically narrowed bronchi, and these again near cavities as large as ordinary vomicæ, surrounded by fibroid bands, emphysematous lobules, and lastly, pleuritic thickenings, we should not be surprised if we meet simultaneously noises belonging to each of these conditions, interspersed with certain areas in which we would find diminution or absence of all sound, whether normal or adventitious. This is the case to such an extent that a differential diagnosis, based upon physical signs alone, is not to be trusted.

Treatment.—One of the first indications in the treatment of any chronic discharge from a mucous membrane is to disinfect it, for experience proves that in so doing we remove a leading cause of the inveteracy of the complaint, viz., local irritation of the membrane by its own perverted secretion. It has been pithily said that it is no business of a mucous membrane to secrete mucus, but rather only an aqueous, slightly saline fluid, with but a trace of mucus to diffuse it equally over the surface. The presence of a layer of mucus, therefore, is a sure sign of something wrong, and we may add that the longer that layer is allowed to remain, the more it acts as an irritant by its fermentative operation upon the subjacent membrane. In practice, there can be no doubt that the sooner mucus is removed, the sooner will an inflamed membrane recover, as we see illustrated by washing the bladder in cystitis. But washing is only a mode of disinfection, and hence illustrates the same general principle. In the alimentary canal, the natural gastro-intestinal secretions are each strongly antiseptic, and therefore the presence of a gastric or of an intestinal catarrh is evidence of the absence of those preservative, as well as digestive, juices. The best remedy for catarrhs of that mucous membrane, therefore, is the restoration of those secretions. On the other hand, where those secretions cannot reach, as in chronic dysentery, I have repeatedly succeeded in arresting, without any internal medication, the muco purulent discharge from old rectal ulcers simply by ordering the rectum to be thoroughly washed out after each passage by an enema of hot water, made disinfectant by the addition of twenty drops of the oil of peppermint.

I refer thus generally to the subject only to emphasize the more that prime indication in managing so intractable a disorder as chronic bronchitis, for next to the lesser exposure of the skin to chill, it is plain that the mitigation of a bronchitis during the summer season is owing to the fact that the patients are at that time able to inhale the open air so much more continuously than when they are jealously housed in winter. The open air is "bland," not because it contains some soothing ingredient characteristic of a given locality, but simply because the oxygen which it contains is the natural disinfectant for the respiratory passages. The best, indeed the only *curative* prescription for a settled case of chronic bronchitis, is a place where the patient may spend two or more years in continuous outdoor life, preferably in a tent, and sleeping in a hammock, because all catarrh will cease when the air tubes have become thoroughly disinfected. The choice of climate, therefore, is not to be regulated by its heat or its moisture, or the reverse, but rather by the number of days in which it is comfortable to remain outdoors without exposure to chill.

Another prime indication subserved by open-air life is the toning-up of the weakened bronchial muscles and of the heart. Throughout the whole animal kingdom, the muscular power is directly proportioned to the activity of the respiration, that is, to the amount of oxygen taken into the system. It is the wonderful breathing capacity of insects which explains their wonderful muscular energy, and so soon as muscular tissue begins to weaken, or is prone to fatty degeneration, the greater is the need to afford it the freest supply of oxygen This principle, therefore, illustrates the clinical fact that one of the most efficacious remedies in chronic bronchitis, and especially in the bronchorrhœa of the aged who have enfeebled hearts, is iron. As the only rôle of iron in the system is to carry oxygen, so I have been accustomed to prescribe the tincture of the chloride of iron, with excess of hydrochloric acid, in every case of heart disease and of chronic bronchitis, as a prophylactic against dilatation or muscle failure, with the result of greatly diminishing the expectoration in the bronchial trouble and enabling the patients to sleep much more continuously at night. In distinction from its effects in phthisis, iron is always well borne in chronic bronchitis, partly, no doubt, from the more febrile character of the former disease. As adjuvants to iron, we may recommend the ethers, such as the compound spirit of ether, the spirit of nitrous ether, dulc., and, in cases in which there is cardiac complication, digitalis.

A certain class of remedies may also be chosen for their antiseptic powers, such as the balsams and terebinthinates like copaiba, buchu, tolu, etc. The objection to them, however, is that they are apt to disorder the stomach, and hence can be employed advantageously only now and then, especially on some exacerbation of the chronic disease with pain and increased coughing Carbolic acid itself, made up into pills and taken in doses of about twelve grains a day, is more effective and better borne. A drink composed of twelve grains of carbolic acid, half an ounce of glycerin, and half an ounce of paregoric in a pint of water, to be taken through the day, is a frequent prescription when the cough is severe and the expectoration at all offensive. One of the best remedies of this class is the carbonate of creosote or creosotal, on account of its agreeing so well with the stomach, as it often improves the appetite and digestion. An emulsion of it can be made readily with a small quantity of glycerin so that a tablespoonful will contain twenty grains of creosotal, the ordinary dose, to be taken three or four times a day. On the same principle we would recommend the daily use of inhalations of carbolized steam, described in the article on *Asthma*. The use of quinine, also, as an antiseptic, in moderate daily dose, however, is to be recommended on general principles, particularly when there is free secretion of pus. The nitric acid, in combination with the iodide of potassium, is sometimes of great service in profuse expectoration, especially when there is reason to diagnose the presence of sacculated bronchial cavities. In some of these cases the oxide of zinc, with belladonna, has seemed to diminish secretion, as it does in phthisical cavities with profuse expectoration.

In those cases in which the expectoration is very viscid, and the cough correspondingly severe, I have found no remedy equal to the emulsion of linseed oil, already referred to. It soon renders the sputa less tenacious, and similarly lessens the violent coughing, while it seems to promote a restoration to a more healthy circulation by lessening the congestive tumefaction through the specific action of oils on such conditions in mucous membranes. The aid of chloral and morphine is also valuable here in checking the irritability of the bronchial nerves. In this class of cases a good deal of benefit may be derived from a prolonged course of mineral waters; those containing the largest proportion of common salt are to be preferred. Such a course is also to be recommended in those cases, above described, of lithæmic or of gouty tendencies, and in the bronchitis of chronic alcoholism. If there be much asthmatic wheezing, the administration of iodide of potassium with belladonna, and occasionally a course of arsenic, will prove of service. In all cases of difficult expectoration, it is well to remember the help which may be obtained from sipping hot drinks. A cup of hot coffee taken thus, before rising in the morning, may enable a patient to rid himself of an accumulation of mucus which otherwise would be voided only by repeated and exhausting efforts.

The importance of protecting the skin of persons affected with bronchitis, in such a climate as ours, cannot be overrated. They should be dressed in buckskin underwear from head to foot throughout the whole autumn, winter, and spring months. The suit should be worn over a light flannel, which may be changed to thicker material in midwinter. All chest protectors should be discarded because they are altogether inadequate for a condition in which a chill to any part of the surface, and especially to the feet is quite enough to set up a fresh access of inflammation When such exacerbations occur, one of the best measures is to resort to free diaphoresis by the hot-water and blanket pack. The patient should go to bed and undergo this thoroughly, three or more times a day, and by so doing he may effectually cut short a severe visitation of his enemy During the summer, it is very desirable that the patient take daily cold salt-water sponge-baths, followed by active friction. This measure certainly lessens the tendency to catching cold, and the same may be said of the use of oil inunctions for the whole body, to be practised every morning in the winter, with the precaution of exposing the body only in a warm room.

The treatment of acute diffuse bronchitis, supervening upon the chronic form of the disease, belongs more properly to the subject of broncho-pneumonia.

William H. Thomson.

BROOM. SCOPARIUS.—*Broom-tops.* "The tops of *Cytisus Scoparius* (L.) Link. (fam. *Leguminosæ*)" (U. S. P.). This is a densely growing, erect, yellow-flowered shrub of Europe and adjacent Asia, two to five feet high, its branches terminating in thick masses of long, exceedingly slender twigs, which are used like brooms, whence the popular name. These twigs constitute the drug of commerce. They are two to three feet long, one-eighth to one-fourth inch thick, sharply five-angled, of a very dark green, and exhaling a peculiar odor when bruised. This odor largely disappears with time, when the drug becomes inferior. The leaves, which are rarely present, are sub sessile, trifoliolate or reduced to one leaflet, the latter oblong or oval or obovate, somewhat hairy. Yellow papilionaceous flowers are often present, and perhaps some flat pods, looking like undeveloped pea pods.

Composition.—Broom contains tannin, fixed and volatile oil, wax, and the two peculiar bodies *scoparin* and *sparteine*. The volatile oil slightly assists the diuretic action of the scoparin. The latter is an amaroid ($C_{21}H_{22}O_{10}$), amorphous or in yellowish crystals, soluble in alcohol or hot water, and diuretic by directly stimulating the renal secretion. It is occasionally given in doses of 0.5 to 1.0 gm. (gr. vii.–xv.), but is a very expensive remedy. Sparteine ($C_{15}H_{26}N_2$) is a yellow, syrup-like, aromatic, volatile alkaloid, soluble in alcohol and water, and yielding crystalline salts. It is a powerful poison. It has a primary circulatory stimulant action, contracting the arterioles and increasing blood pressure, thus assisting the diuretic action of the scoparin and volatile oil. The secondary action, which is very prompt, is to weaken the heart muscle and partly or wholly to overcome the vaso motor contraction. The drug is thus a cardiac sedative and in over-doses a paralyzing cardiac poison. It is also sedative to other muscles, and may act as a mild anodyne. It was originally used as a cardiac stimulant, but was found disappointing, and is now little used, mostly in the form of the official sulphate, in doses of 0.01 to 0.02 gm. (gr. ⅙ to ⅓).

Broom is very considerably employed as a diuretic. The fluid extract is official and is given in doses of 1 to 4 c.c. (¼ to 1 fl. dr.). The five-per-cent. infusion is a better form of preparation, in doses of one-half to one ounce *Henry H. Rusby.*

BROWNSVILLE, Texas, a town of 6,130 inhabitants, is situated on the north bank of the Rio Grande River, opposite Matamoras, in the extreme southeastern corner of the State. It is a port of entry, and has a warm, moist climate. It is not a health resort, and is mentioned here simply to indicate the climatic conditions which exist in this section of the country.

CLIMATE OF BROWNSVILLE, TEXAS. LATITUDE, 25° 53′; LONGITUDE, 97° 26′. PERIOD OF OBSERVATION, SEVEN AND ONE-HALF YEARS. ELEVATION OF PLACE OF OBSERVATION ABOVE SEA LEVEL, TWENTY-EIGHT FEET.

Data.	January.	July.	Year.
Temperature (Fahrenheit scale)			
Average mean	59.5°	84.4°	73.1°
Average range	17.2°	15.2°	
Mean of warmest	66.9°	92°	
Mean of coldest	49.7°	76.8°	
Highest or maximum	83°	98°	
Lowest or minimum	18°	68°	
Humidity –			
Average relative (per cent.)	79.6	71.9	76.3
Precipitation –			
Average in inches	2.10	2.63	32.03
Wind—			
Prevailing direction	N.	S. E.	S. E.
Average hourly velocity in miles	7	6.9	6.9
Weather—			
Average number clear days	8.1	13.3	116.3
Average number fair days	8.1	14.2	148.9
Average number fair and clear days	16.2	27.5	265.2

NOTE.—If the above chart is not self-explanatory to the reader, he is referred to the article upon *Baltimore*, where in a similar table some of the terms are commented upon.

Edward O. Otis.

BROWN'S WELLS.—Copiah County, Mississippi.

POST-OFFICE.—Brown's Wells. Hotel and cottages.

ACCESS.—Viâ Illinois Central Railroad to Hazelhurst, thence five miles by stage line to springs.

Brown's Wells are situated near the central part of Mississippi, 40 miles south of Jackson and 150 miles northeast of New Orleans. The location is among the pine hills of Mississippi, though hickory, oak, and other growths abound. The climate here is very salubrious, and extremes of either heat or cold are seldom observed. The temperature rarely falls lower than 20° F. in the winter or rises above 98° F. in the summer. The elevation above the sea level is quite considerable. The resort is open for the reception of visitors all the year. Four springs are found in the neighborhood, but only two have been analyzed. Examination of Spring No. 1 was made by Prof. John R. Chilton, of New York, with the following result·

SPRING NO. 1.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium sulphate	17.76
Magnesium sulphate	45
Calcium sulphate	97.60
Aluminum sulphate	8.11
Iron protosulphate	36.52 (?)
Calcium chloride	16.44
Organic matter	.92
Free sulphuric acid	40.88 (?)
Total	263.23

This analysis shows a very potent mineral water. It is probable, however, that the chemist's report has been misread in some of the findings, and a new analysis is consequently desirable. According to a quantitative analysis by State Geologist George Little, Spring No. 2 contains

Calcium carbonate.
Magnesium carbonate.
Sodium carbonate.
Iron sulphate.
Alumina.
Organic matter.
Carbonic acid gas.
Sulphureted hydrogen gas.

The proprietor of the springs, Mr. M. L. Morehead, presents many testimonials from well-known physicians certifying to the value of the waters. They are said to be very useful in rheumatic and gouty disorders, in obstinate disturbances of the alimentary tract, in functional liver complaints, in dropsical affections due to nephritis, and in anæmia and allied disorders. *James K. Crook.*

BRYONY. BRYONIA.—"The root of *Bryonia alba* L. and *Bryonia dioica* L. (fam. *Cucurbitaceæ*)" (U. S. P.). There are eight species of Bryonia, natives of the Mediterranean region. The *B. dioica* grows as far north as England. They are tendril-bearing, cucumber-like vines, with very large, starchy roots, growing mostly in sandy soil. Their bitter and active constituents are doubtless for the protection of their nutritious roots against foraging animals.

The roots are sliced, mostly transversely, to facilitate drying. These commercial slices are white discs (becoming gray with age), from one to four inches in diameter and one-fourth to nearly one-half inch in thickness. They are not appreciably thinner at the centre, though the bark is slightly broader than the fleshy portion. There are several concentric circles of short wood bundles. The surface is granular and slightly harsh to the touch. The fracture is short and sharp. There is a characteristic, though faint odor, and a powerful and disagreeable bitter taste. It is not adulterated

Composition.—With much starch and gum, and some sugar, the active constituents are the two bitter glucosides *bryonin* and *bryonidin.*

Action and Uses.—Bryony is a hydragogue cathartic, practically identical with colocynth and elaterium. Like these, also, it is a stimulating or irritating diuretic, and thus emmenagogue, for which latter purpose it has been much employed. It is poisonous in over-doses. A ten-per-cent. tincture is official, the dose being 8 to 15 c.c. (2 to 4 fl. drs.). The extract, dose 0.2 to 0.4 gm. (gr. iii.–vi.), is a preferable form of administration

H. H. Rusby

BUBO (from *βουβών*, the groin; Ger., *Leistenbeule;* Fr., *bubon*), a term originally used by medical writers of antiquity to designate glandular tumors of the groin, was applied by authors of the period of the Reformation to glandular inflammations of every part of the body irrespective of their nature. Modern writers have again reserved the term for inflammatory affections of the lymphatic glands of the groin. While buboes are alluded to in the earliest medical treatises of which we have any knowledge, and the pathogenetic importance of the genitalia in their causation was apparently familiar even to Hippocrates, the distinctive types of the affection which are now generally recognized were, of course, unknown until long after the general outbreak of syphilis, which appeared at the close of the fifteenth century. Then, besides the adenitis, which suppurates and often leaves an ulcer, there presented itself a bubo which from its inception is indolent, unattended by pain, and rarely the seat of suppurative change. Gaspard Torella, Fallopius, Nicolaus Massa, Paracelsus, and other writers of that memorable epoch in the history of venereal diseases speedily recognized and described with sufficient accuracy this earliest systemic manifestation of syphilis. Nevertheless, the nature of buboes was so little comprehended that they were regarded as sympathetic in character, or as unsuccessful endeavors of nature to check through them the invasion of the system by the disease. That the majority of buboes result from the deposit in the lymphatic glands of a poison conveyed to them from a distance could not have been known prior to the discovery in 1651, by Oläus Rudbeck, of lymphatic vessels situated in different parts of the body and possessing a function of absorption like that of the lacteals previously described by Asseli. Even then precise knowledge of the subject was slowly developed, and it remained for the observations of Hunter, Swediaur, Benjamin Bell, and Ricord to depict the clinical symptoms and finally establish the etiological relations of the different varieties of the disease under consideration.

Anatomical and Pathological.—The subcutaneous cellular tissue of the groin encloses, together with the superficial blood and lymphatic vessels, a varying number (eight to twelve) of lymphatic glands, which receive their lymph from the subumbilical segment of the anterior abdominal wall, from the external genitalia, urethra, perineum, vagina, cervix uteri, anus, and inferior extremity. The size of the inguinal, as of other lymphatic glands, in their normal state is so small that in persons with a *panniculus adiposus* of ordinary thickness they cannot be felt through the skin. Oval or elongated in form, the glands of the groin are arranged in two quite distinct groups, the larger of which follows the course of Poupart's ligament, while the smaller forms part of the cribriform fascia covering the saphenous opening. The individual glands of these groups, when naturally large or enlarged from disease, present distinctive directions. Those which overlie the ligament have their axes parallel to the inguinal fold, while those of the lower group have their axes parallel to that of the lower extremity. This factor is of considerable importance, in that it often gives a clue to the source of the ganglionic complication, since the lymph from the external genitalia is conveyed to the upper, while that from the lower extremity passes to the lower chain. It must not be forgotten, however, that these groups communicate very freely with each other by numerous lymphatic vessels, in which the circulation is from the upper to the lower glands. Indeed, it is through the glands over the saphenous orifice and through one or two glands (Rosenmüller's) deeply seated underneath the *fascia lata*, that the lymph must pass from both lower extremity and genital area before it can enter the general lymph receptacle in the abdomen. This anatomical factor will account for the not very infrequent occurrence of two suppurating glands on the same side of the body, of which one belongs to the upper and the other to the lower chain, the inguinal fold lying between them.

Formed of a capsule embedded in the periglandular adipose tissue, containing within it lymph sinuses networks of reticular connective-tissue and lymph cells, the lymphatic gland, when the seat of inflammatory changes, presents appearances which vary greatly with the degree of the inflammatory process and the nature of the primary cause. The acute adenitis which may follow in the wake of any traumatic or specific infection of the skin or mucous membrane, and which manifests itself clinically by moderate swelling and tenderness of the affected gland, is associated with dilatation of its blood vessels and proliferation of the lymph corpuscles contained in the meshes of the reticular network or stroma.[1] When this cellular infiltration becomes excessive the reticular network suffers from compression; it becomes rarefied, the capillaries are obstructed or completely torn. When deprived of their nutrition the infiltrating cell masses are speedily converted into pus foci. Through the confluence of these the gland capsule, already distended from the inception of the process, becomes an irritant to the surrounding parts; the subcutaneous cellular layer and the skin more or less rapidly participate in the morbid changes, and soon the suppurating bubo, having attained twenty fold the size of the normal gland, is emptied spontaneously or by the knife of the surgeon. After the evacuation of the pus the abscess cavity speedily contracts, and cicatrization ensues with such rapidity at times that the wound is closed in a week from the opening of the bubo. Not always does this process of repair follow so quickly the elimination of the pus. The behavior of the periglandular tissue is a most important factor in the events that are to follow. This is often the seat of more extensive inflammation than the gland itself. Minute abscesses form around the inflamed gland from obstruction of its afferent vessels, so that after the elimination from the gland itself this remains embedded in a secondary abscess cavity formed about it. Covered by granulations it may in time appear as a foreign body in the floor of an ulcer, or it may remain for months covered by integument yet surrounded by indolent sinuses. Nor is the pathological process that ends in suppuration necessarily limited to one gland alone. The infection may be conveyed from the gland originally involved to one or more in the vicinity, until a number of them are bound together in one large inflammatory nidus, the suppuration of which usually entails the destruction of a considerable extent of skin. To a large extent, the termination of an adenitis depends upon the nature and gravity of the primary disease. If the irritation in the lymph radicles of the affected gland is mild or evanescent, as in herpes, balanitis, erysipelas, or gonorrhœa, the consecutive adenitis rarely proceeds to suppuration. Absorption of the infiltrating cellular elements may supervene in a few days or even hours. On the other hand, long continuance of the local irritation, whatever its character, will at times completely change the results of the glandular inflammation in that the cellular infiltration, being insufficient in extent to induce suppuration, yet not disappearing by absorption, leads to organization. Here it is not the exuded lymph corpuscles that are converted into a durable tissue, but the reticular substance which forms the framework of the gland. In the suppurating adenitis this disappears; in subacute adenitis it undergoes a reactive hypertrophy. In the course of time the septa of the gland increase so greatly in thickness that the lymph corpuscles between them are seriously encroached upon. Hence the firm fibrous appearance of the section of a lymphatic gland that has been the seat of a chronic inflammation.

Etiology and Varieties.—The inguinal glands differ in no way from those of other parts of the body, and the morbid processes to which they are subjected can be duplicated in those of the groin. Hence *a priori* reasoning as to the venereal origin (using the term in its widest significance) of an adenitis here situated must be strenuously deprecated. Violent exercise, strains while lifting or while mounting a horse, direct trauma, herpes, furuncles, eczema genitalium, and scabies may all be the source of an inguinal adenitis. Some time ago there appeared at my clinic a lad of seven years, with two suppurating glands, the one above, the other below the ligament. The most careful inspection of genitalia and lower extremity failed to reveal anything abnormal. The cervical glands were not enlarged, nor were there traces of tuberculosis or syphilis discernible. The only adducible cause of the bubo was a severe fall from a sand bank, which the boy had sustained one week before aggravated symptoms supervened. Buboes such as these, which in no way depend upon an inoculable, undiscoverable primary disease, and which stand neither immediately nor remotely in connection with the sexual act, I have been in the habit of designating *non-venereal buboes.*

Each of the three typical venereal affections, viz., gonorrhœa, the chancroid, and the initial lesion of syphilis, may be attended by complications of the inguinal glands, which are known as *venereal buboes,* and are subdivided into, 1, the simple or inflammatory; 2, the virulent, and 3, the syphilitic varieties. They are produced respectively (1) by the irritation of a gonorrhœa and chancroidal or syphilitic ulcer; (2) by the chancroid solely, and (3) by the presence of the initial lesion alone.

1. Buboes are rarely produced by gonorrhœa. While a slight tenderness of the neighboring glands not infrequently attends a urethral discharge, it is very exceptional to witness in them an inflammation that ends in suppuration. Ferry states that in the United States Marine Hospital Service two and one-half per cent. of gonorrhœas are followed by suppurating buboes (*Jour. Amer. Med. Sc.*, 112, p. 571). In three hundred and twenty-seven cases of gonorrhœa seen by Sigmund, suppurating buboes developed in nineteen. Yet buboes of considerable size, with extensive destruction of tissue, are occasionally encountered as complications of gonorrhœa. They have been met mostly in very young subjects, in persons of tuberculous habit, or in subjects debilitated by a previous attack of syphilis. Again, it is not unusual to find a chronic hyperplasia of one or more of the inguinal glands after repeated and prolonged urethral discharges, a condition analogous to that of the cervical glands in persons prone to catarrhal affections of the throat. The term "sympathetic bubo," formerly applied by preference to gland complications of gonorrhœa, is gradually being discarded. Whether the bubo results from purulent preputial catarrh, gonorrhœa, or chancroid, instances are not rare in which there can be detected that cord-like swelling along the dorsum of the penis which is but the evidence of a lymphangitis developed by direct propagation of the disease from its first seat. Still, the morbid process in the lymphatic vessels does not usually manifest itself by perceptible symptoms. Like the *vas deferens* in epididymitis, the lymphatic vessel conveys the irritant to the gland without being often seriously affected by it.

2. The chancroid is by far the most common precursor of the bubo. From its very inception to the period of its repair, and even for months after its complete closure, the chancroid may be the cause of an inflammatory bubo. This the soft sore may accomplish in its dual capacity of harboring the ordinary pus-formers and the special bacillus of Ducrey and Unna. Ricord formulated the law that when the chancroidal virus is absorbed into a lymphatic gland there must inevitably be a suppurating bubo, the pus from which, in turn, will reproduce a chancroid. When the pus from a bubo of chancroidal origin is not inoculable, it is presumed that the fluid absorbed from the chancroid did not possess the characteristic qualities of chancroidal virus. This is the distinguishing feature between the simple and virulent buboes originating in chancroids. Still, it is difficult to comprehend why a large, suppurating, yet non-virulent bubo should follow from the irritation of so small an area as is usually covered by a chancroid, when it so rarely follows the infinitely more extensive irritation of the urethra from gonorrhœa. It has been estimated that the proportion of simple to virulent buboes (following chancroids) is nearly equal; it being 149 simple to 138 virulent.[2] These figures are far from conclusive, since every case should be made the subject of most careful inoculation before being utilized in statistics. The relative frequency of buboes in general as a complication of chancroids has been more accurately determined. Fournier[3] has observed 207 chancroids of which 65 were complicated by suppurating buboes.

In 146 cases of chancroid observed at my dispensary in the Medical College of Ohio, during a period of two years, suppurating buboes were recorded in 40. Thus it appears that in about 28 per cent. of the total number of chancroids buboes appear. In private practice the proportion is not so large, since with proper treatment of the primary ulcer ganglionic infection can generally be averted. It is a remarkable fact that in women buboes are not so prone to develop as in men, owing probably to the fact that the latter cannot abstain from work for a trivial soft chancre. The size of the original sore does not appear to influence, in any manner, the action of the inguinal glands, since it is not unusual to find destructive buboes following small and superficial ulcers, while destructive chancroids remain uncomplicated. The retention of the discharge from the chancroid is, no doubt, an important element in the production of buboes, since those of the frænum and those associated with phimosis are relatively most often followed by them. With few exceptions the chancroidal bubo develops in the groin of the same side occupied by the first sore. When this is situated in the median line, and particularly when it involves the frænum, bilateral buboes are apt to supervene. Only in very exceptional cases is the irritation or virus conveyed across the median line, to the glands of the opposite side, through the anastomosis of the lymphatic vessels. Occasionally a bubo will form in the median line at the root of the penis, or in the pubic region, where a small lymphatic gland is often found at the confluence of the lymphatic vessels of the two sides. Pubic buboes were encountered in 3 out of 298 cases.[4]

The pus from chancroidal buboes is ordinarily sterile and free of micro-organisms. Inoculation with it as a rule fails. This has been shown by Strauss, Spitscka, and others. The most extensive investigations relative to this question have recently been made by Deutsch.[5] He examined the pus from 66 buboes. Thirty-seven occurred with the soft sore, 29 with the hard or mixed ulcers. Bacteriological experiments were made with a view to establish auto-inoculability, and to determine the length of time required for the bubo to heal. Of the 37 cases occurring with the chancroid, inoculation upon the abdomen with the production of a typical chancroid was successful in only 3 cases. In these 3 cases the pus from the bubo showed the Ducrey bacillus. The pus from chancroidal buboes could be classified under three categories: (*a*) Sterile pus; (*b*) pus containing ordinary pus formers; (*c*) pus containing the Ducrey bacillus with or without the admixture of other microbes. In the 29 cases occurring with the hard or mixed sore, auto-inoculation was successful in only 3 cases, and in only 1 was a typical hard sore produced. It may safely be stated, therefore, that in the great majority of cases suppuration in buboes is the result of toxic absorption, and is not due to the entrance of micro-organisms themselves into the lymph channels and nodes.

3. Syphilis. The initial lesion of syphilis is almost invariably followed by a sclerosis of the upper chain of the inguinal lymphatic glands, of which the innermost is first involved during the first fortnight after the primary sore manifests itself. In the course of a few weeks the other glands of this region (*Pleiades ganglionnaires*), and subsequently the glands in general, become affected. Fournier failed to find induration of the inguinal lymphatics 5 times in 265 cases; Berkeley Hill[6] 3 times in 176 cases; whereas Bumstead[7] has never "met with a chancre which was not attended by induration of the neighboring lymphatic ganglia." It is a characteristic of the syphilitic

bubo that it involves the entire chain of lymphatic glands, and that its progress is not attended by acute symptoms. Hence this form of bubo is often termed *indolent*. In its morbid anatomy nothing of an inflammatory nature is apparent. The small-celled infiltration which takes place in the initial lesion of syphilis is reproduced in the inguinal glands. Every mesh of the reticulum is fully distended by cells. The induration resulting therefrom continues for months, and even for years, without terminating in inflammation or necrosis of the gland. As in the case of the primary induration, after continuing for a varying length of time, a fatty metamorphosis of the cells ensues; the detritus is absorbed, and the gland returns to its normal condition (Rindfleisch).[8] In galloping syphilis and in that of lymphatic subjects, the inguinal glands at times undergo extensive suppuration. Even then it will be found that the immediate cause of the inflammation is a secondary pus infection of the primary ulcer, with the development in it of phagedæna. This suppuration of an indolent bubo, therefore, has neither a favorable nor a contrary influence on the subsequent course of the syphilis. While the suppurating adenitis is, as a rule, a sequel of the soft chancre, its presence does not infallibly demonstrate the non-infecting (chancroidal) character of the primary sore.

Bubon d'Emblée.—The buboes which have been thus far considered are ascribable to plainly discernible lesions in the area of origin of the lymphatic radicles of the affected gland. Therefore they are secondary in character. The question has for a long time been discussed whether, without the development of a lesion at the point where the virus entered the body, this could be directly absorbed and conveyed to the glands and produce in them its peculiar pathological effects. Authorities of great weight (Vidal, Reynaud, Benjamin Bell) have cited numerous instances in which such absorption without local reaction is supposed to have taken place. To designate this particular form of ganglionic disease the terms "primary bubo," "idiopathic bubo," and "bubon d'emblée" have been used as synonyms. It has already been observed that primary buboes could arise from direct trauma, excessive exercise, strumous habit, and other like causes. Aside from these etiological factors, it is at present deemed impossible for a venereal bubo to develop without preexisting primary trouble. It is within the experience of every one that this primary affection may be very trivial in extent and of remarkably short duration, therefore escaping the attention of the patient. Here, as in the case of the minute dissecting wound that may lead to suppurating lymphadenitis, and even to death, the original lesion, or some trace of it, can always be found. Until it can be demonstrated that chancroidal pus or syphilitic virus can be made to permeate the unbroken skin, there is no good cause for believing in the bubon d'emblée. It is particularly through the efforts of Ricord, Langlebert, Fournier, and others that the "idiopathic bubo," for so long a period the subject of most ardent polemics, is now generally believed to have no actual existence.

SYMPTOMATOLOGY.—*Simple Bubo.*—The appearance of an inguinal bubo is ordinarily announced by a feeling of discomfort while walking. A passing sense of fulness causes the patient to examine the part, when he finds one or more tender glands in the groin. Palpation at this time reveals the presence of a resistant, movable swelling, tender to the touch, and varying in size from a bean to a cherry. Within a few days the symptoms rapidly increase in severity. The tumefaction, increasing in extent, is oblong in form with the long axis parallel to the groin when a gland of the upper chain is affected, and parallel to the axis of the thigh when one of the lower group is involved. A decided elevation of the skin becomes apparent before its implication in the process occurs. Pain is usually complained of, and it is either sharp and spasmodic in character or dull and constant. Hence follow disturbed sleep and impeded progression. With the extension of the inflammation to the periglandular tissue, the mobility of the swelling disappears, the tumor loses its well-defined outline, the skin itself becomes adherent and the seat of more or less redness. Even when symptoms so pronounced as these have continued for a week or more, resolution may supervene in the course of two or three days. Such a fortunate termination is more likely to ensue when the primary affection was a gonorrhœa, balano-posthitis, or herpes. But in undoubted cases of chancroid a gradual resolution of the acute inflammation, or its termination in a chronic induration, is not at all infrequently observed. These terminations are quite as likely to follow in the buboes which supervene during the early stages of the chancroid as in those that attend the reparative process of the sore or that follow its cicatrization.

When the inflammation passes to the suppurative stage the indurated mass generally presents a softer spot, which is as often situated out of, as in, the centre of the swelling. With the increase of the area of softening the skin changes to a dusky hue. An examination, while the skin is still intact, reveals distinct fluctuation, and when the attenuated integument is indented by the finger the indurated wall of the abscess can ordinarily be distinguished. It is at this time, from ten days to two weeks after the beginning of the bubo, that the pus is usually evacuated by incision. In quantity this does not often exceed an ounce. If left to itself, weeks will often elapse before the skin yields to the ulcerative process, during which time the abscess increases in its dimensions until it contains at times from four to six ounces of thick, creamy pus. When permitted to open spontaneously, the abscess usually opens at one point only, although two or three apertures are often formed. This feature of inguinal suppurating buboes requires especial mention. When the swelling has attained the size of a walnut or small peach, it will often appear to be subdivided by a deep furrow into two quite distinct growths, of which the smaller is usually situated below and nearer the median line. When suppuration is finally established, a separate opening will be formed or made necessary for each division of the swelling, irrespective of the question as to whether more than one gland is involved. Not always does the suppurating bubo run so acute a course. Instances are not at all infrequent in which the inflammatory symptoms develop in successive stages with intervals of quiescence. Such buboes often require several months before maturing, and for these cases the term "subacute" is occasionally reserved. The pus contained in them is usually watery in character, and ordinarily not very abundant.

The clinical course of a simple bubo, after it has discharged, does not differ materially from that of an abscess from other causes. In about thirty per cent. of all cases, and particularly in those in which an early incision was made, the walls of the abscess become agglutinated, and suppuration rapidly ceases. Generally, however, the discharge continues for from one week to many months before the abscess cavity is obliterated. Chronicity of discharge characterizes particularly those abscesses in which more openings than one have formed, and in which sinuses lined with exuberant granulations undermine the skin. In many of these cases, the force of the inflammation having been spent on the periglandular tissue, these sinuses lead down to one or more glands. When the integument covering the sinuses finally yields to the suppurative process, or is divided by the knife, the gland covered by granulations will appear in the floor of the ulcer or in the wound thus produced.

Virulent Bubo.—With the conveyance of the ptomaïns or of the specific microbes from the chancroid to the lymphatic gland, suppuration in the latter is inevitable. The bubo of absorption, which results from this, in its inception presents symptoms precisely like those that belong to the simple bubo. The rapidity of development of the symptoms alone might arouse suspicions as to the virulent form of adenitis. It is only after the evacuation of the abscess that the differential diagnosis becomes practicable. Inoculation with the pus of the virulent bubo invariably produces a chancroid; inoculation with the pus from a simple bubo yields negative results save in syphilitic subjects (*vide supra*). But the inoculation test is superfluous, since the progress of the virulent bubo after it is opened is usually sufficiently pronounced. The margins of the wound which gave passage to the pus become inoculated with the chancroidal virus. As in the chancroid, during its period of progress the integument covering the virulent bubo is rapidly destroyed until a true chancroidal ulcer, varying much in area and depth, presents itself in the groin. When fully exposed to view, the floor of the bubo, from absorption, presents the yellowish-gray, irregular, and worm-eaten appearance of the chancroid. The margin of the ulcer, tumefied at one part, appears attenuated or undermined at another. From the entire surface there is exuded a watery pus which is often tinged with blood. Capillary hemorrhages from the bubonic ulcer are often encountered as in the chancroid. Indeed, the clinical history which belongs to the chancroid is on a larger basis duplicated in the case of the bubo. Healing in rare instances in a few weeks, in less fortunate cases it continues in its destructive course for months, and occasionally even for years. When thus protracted, the ulceration usually assumes the serpiginous type, healing in one portion and extending in another. Thus the ulcer gradually spreads over abdomen, thigh, pubes, or gluteal region, leaving frequently ungainly cicatrices. In these cases the ulcerative action is often so sluggish that, as in lupus or rodent ulcer, it is almost imperceptible. Continuous auto-inoculation of the skin in the vicinity of the ulcer is the only plausible explanation of these protracted forms of bubo. Phagedæna, that most terrible complication of the venereal sore, occasionally attacks the virulent bubo. Under its influence the bubo may in a few weeks become converted into an ulcer the size of the palm. Superficial in some cases, in others the ulcer under its influence dips down into the tissues, producing extensive sloughs. Progressing among the blood-vessels, it has been known to open them and induce fatal hemorrhage Fatal results have likewise been induced by the excessiveness of discharge and from pyæmia.

Syphilitic Bubo.—The inguinal adenopathy of syphilis is but the reproduction on a larger scale of the indurating process manifested in the primary lesion. Appearing early and affecting an entire group of glands, the syphilitic adenopathy yields a row of larger and smaller tumors, freely movable and easily felt, except in very obese subjects. These tumors are hard, resistant, not tender to the touch, and usually largest on the side of the primary sore. Oftener than in the other forms of bubo, the dorsal lymphatics of the penis participate in the morbid process and appear in the form of indurated cords with irregular nodosities. Like the enlarged lymphatic glands, these lymphatic cords are freely movable. It has already been observed that indolence characterizes the syphilitic bubo. Only in persons of scrofulous taint, and in cases of great malignancy of the syphilitic virus (galloping syphilis), does suppuration ensue. With or without treatment, the syphilitic bubo continues while the primary and many of the secondary manifestations remain. It is rare to find these buboes subside completely, even under treatment, in less than two or three months, and in many instances they survive all other syphilitic lesions, when they assume great diagnostic importance in determining the presence or absence of a syphilitic taint. After continuing sometimes in an unaltered state for two or three years, they finally subside spontaneously.

TREATMENT.—The treatment of buboes must necessarily vary with the nature of the primary trouble. In a prophylactic way nothing can be done to prevent the syphilitic bubo, while much can be accomplished in the prevention of simple glandular inflammations as complications of the chancroid and gonorrhœa. In both these affections violent exercise and excessive walking and riding should be strictly interdicted. Irritant applications to the primary disease should be strictly avoided, since too astringent urethral injections and irritating ointments applied to chancroids are often the immediate causes of gland complications. What influence has the cauterization of the chancroid upon the development of buboes? If statistics be carefully examined, it will be found that in about thirty per cent. of all cases buboes supervene, and that their development is uninfluenced by the use of, or abstention from, cauterization. For this reason the application of violent caustics to chancroids is being more and more discarded. Of much greater importance as a prophylactic is cleanliness and the securing of a free escape for all discharges. It is for this reason that chancroids treated in private practice are much less often complicated by buboes (according to my experience, one to eight) than those of hospitals, and particularly of dispensaries.

When the evidences of an adenitis become unmistakable, every effort must be made to bring about resolution of the inflammation, since this favorable termination is possible in every instance save those in which the chancroidal virus has been observed. As in other inflammations, rest in bed is the chief antiphlogistic measure, and its importance must be fully explained to the patient. Applications of very cold cloths will at this time prove serviceable. A rubber bag is preferable, since it acts at the same time as a compressor. Local applications of the *liquor plumbi subacetatis*, with cold compresses, have been highly recommended by Hamilton and Zeissl, and are doubtless often beneficial. It is at this period of the inflammation that repeated applications of the *tincture of iodine* are so frequently resorted to. Although this practice has stood the test of time, and has the sanction of eminent authorities, it seems to me devoid of benefit and often pernicious in its results, since it not infrequently is followed by violent inflammation of the skin and hair follicles, even to the extent of vesication. Another important objection to the tincture of iodine is the fact that the artificial condition of the skin produced by it frequently prevents the early detection of suppuration. When, for the purposes of absorption, iodine seems indicated, I have lately employed the iodide of lead quite extensively, using in connection with it veratrin, belladonna, or opium to allay pain. Inunction with iodine-vasogen, six per cent., likewise serves a good purpose. Since compression, where it is practicable, plays an important rôle in the treatment of inflammations, it should be used here. It can be best applied by means of a bag half-filled with small shot. If the patient cannot be retained in bed, collodion applications and a compress, held in position with a spica bandage, should be resorted to. Happily for the patients, a number of methods of aborting the inflammation which were formerly practised have been entirely abandoned. Among them may be mentioned methodical compression by instruments, repeated blistering with the subsequent application of mercurials, the forcible rupture of the gland capsule, and the use of the seton. To these may be added the subcutaneous incision of the gland and the somewhat analogous procedure of Auspitz. The latter observer punctures the inflamed gland even before suppuration can be detected. A probe is introduced through the opening and the glandular septa are torn; the substance of the gland is thus broken up and discharges through the exterternal wound. This practice of Auspitz has not found and does not deserve many followers. Nevertheless, it has been most highly indorsed by Bumstead. Intraglandular injections of iodoform emulsion, carbolic acid, and corrosive sublimate have been used to avert suppuration. Welander (*Arch. f. Dermat. u. Syph.*, 1891, H. 3) advocated the injection of a one-per-cent. solution of benzoate of mercury. Of 78 cases reported, 56 were cured without suppuration. Perry (*loc. cit.*) employs it in all non-suppurating buboes, injecting twenty to thirty minims of the solution. More than two injections are rarely necessary and the time required to effect a cure is fourteen days.

When suppuration has been established, the treatment of the bubo must not vary from that of abscesses in other easily accessible portions of the body. *Ubi pus, ubi incisio* is a rule that should be adhered to in the disease under consideration. The ways in which the pus is to be evacuated are numerous. Within the last fifteen years aspiration has often been resorted to, and has been highly recommended by a number of French and German observers. When it is evident that the purulent accumulation is small, and that a suppurative periadenitis has not yet developed, aspiration cannot be too often practised. Attended by little pain, it can do no harm, and is sometimes followed by permanent agglutination of the abscess walls. Among recent writers R. Hahn speaks most favorably of it. In a series of two hundred cases, seventy per cent. were cured by aspiration alone. In three-fourths of the cases one aspiration sufficed (Mittheil. aus der Hamburg. Krank. Anstalt, 1898). When the abscess is large and the skin attenuated, the only hope for a speedy recovery lies in the prompt and complete evacuation of the pus. The use of the Vienna paste, blisters, and multiple incisions to effect this have been properly abandoned. The last-named method, particularly recommended by Vidal, Zeissl, and Langston Parker, and still practised by many older practitioners, is prone to result in the formation of a number of ulcers in the groin. In the great majority of cases, a single incision, with a narrow blade, is all the operative interference called for. Until two decades ago the incision usually made was parallel to the inguinal fold and extended the entire length of the swelling. The result of such an incision is almost invariably a wound the edges of which are in apposition except when the patient is lying down. Again, when ulceration of the margins of the wound ensues, the skin is very apt to become undermined or inverted. Hence very ungainly cicatrices result that might ordinarily be avoided by making the incision in a different manner. A good procedure is the following: The field of operation being prepared in the usual way, local anæsthesia is produced by the ether spray or preferably by the Schleich method (see *Anæsthesia, Local* (*Surgical*), in Vol. I.). The long and narrow knife, while held perpendicularly to the surface of the body, is then gently forced into the centre of the fluctuating area. The skin and capsule of the gland resist slightly the intrusion of the blade. When this resistance has been overcome, the cutting edge of the knife is turned about ninety degrees and then withdrawn. With a little pressure, or by inserting a grooved director into the cut, the accumulated pus rapidly escapes. To prevent a too speedy closure of the opening, it is advisable to insert a strip of iodoform gauze or carbolized gauze, which also insures the ready drainage of the abscess cavity. When this is removed, after remaining twenty-four hours, it will invariably be seen that the aperture, measuring from one-eighth to one-fourth of an inch in diameter, is circular in outline, and sufficiently large to permit the escape of the pus as rapidly as it is formed. The after treatment consists of the application of bichloride gauze fomentations, or the use of the balsam of Peru 10, and castor oil 100, mixture. For cleansing the abscess cavity, injections of of hydrogen dioxide may be called for from time to time. Thus treated the bubo usually heals in from ten days to two weeks. As already remarked, the bubo often has a tendency to point at a number of places, when it of course becomes imperative to use the knife repeatedly. The practice of Milton, who uses a very large needle for this purpose, might profitably be imitated in timid patients and by practitioners unaccustomed to the use of the knife. Not so, however, in case of extensive periadenitis and of virulent bubo. When the abscess is very large, a somewhat freer incision is necessary. Even here it seems to me better to make it parallel to the axis of the limb, irrespective of the direction of the bubo. The wound thus made is more easily maintained patent, and in making it there is manifestly less danger of wounding the deep-seated vessels than from the incision as generally made. Almost immediately after opening a large bubo there will be a sinking in of the integument. In the course of a week, or even less, this skin becomes discolored, curled upon itself, or undermined. Under these circumstances it is always best to remove the cutaneous flaps with a few strokes of the curved scissors, thus converting the abscess into an open ulcer. In other cases fistulæ in the groin continue to discharge indefinitely. They should be freely laid open with the knife or elastic ligature, and the exuberant granulations removed with the sharp spoon. When once the bubo has been converted into an open ulcer its treatment is ordinarily successful, no matter what applications be made, although at times stimulating medicaments are called for to overcome the sluggishness of the granulations. Among the large number of agents specially recommended for this purpose there should be mentioned iodoform, tincture of iodine, tannin, permanganate and chlorate of potash, preparations of iron, and boric acid. Iodoform usually acts so satisfactorily as almost to merit being called a specific in the treatment of the open bubo. Applied in the form of ointment alone, or with tannic acid, or in ethereal solution (iodoform, 8; ether. fort., 30), it soon causes the floor of the ulcer to be covered with small and healthy granulations which rapidly lead to its permanent closure. When the odor of iodoform is an insurmountable objection to its use, the permanganate of potash (0.5 to 30.0), in aqueous solution, is an excellent substitute. The balsam of Peru dressing already referred to also forms an excellent application. When the reparative process is exceptionally protracted, from the size of surface involved, skin-grafting has been used with as much success as in other portions of the body.

Attention has already been directed to the fact that the lymphatic gland covered by granulations often presents itself in the floor of the bubonic ulcer, or is hidden in the depths of a sinus. The gland then acts as a foreign body. It should therefore be removed as soon as it is discovered. Whether this is to be accomplished with scissors, ligature, or Volkmann's spoon must be determined by the circumstances of the case and the predilections of the surgeon in charge.

Excision.—With the development of modern methods of wound treatment excision of buboes, which if left alone would probably suppurate, has become a favorite method of treatment. It is not to be recommended as a routine procedure, because of the extent of operation necessary to remove all glands and of the danger of wound infection from the primary ulcer. Furthermore, the time required for cure, averaging thirty days, exceeds that which is needed when conservative measures alone are adopted.

Excision is indicated when infection has taken place in a number of glands and when it is evident that the process of suppuration will be long continued. By free excision in these cases the healing process can be curtailed as to time. Primary union should not be sought for; in most cases it will fail.

It is self-evident that the systemic treatment of patients afflicted with buboes must not be neglected. Nutritious diet and tonics are always indicated after the process of suppuration has become somewhat protracted. This is particularly true if the ulcer shows any tendency to phagedæna. It is then that cod-liver oil, quinine, and alcoholic stimulants are indicated, and that the most effective local measures must be resorted to. Blisters, fuming nitric acid, the carbo-sulphuric paste, bromine, and even the actual cautery must at times be employed before the tendency of the ulcer to spread is permanently overcome and the process of cicatrization is well established. Fortunately, this class of cases is becoming rarer from year to year.

Syphilitic buboes, as a rule, require no local treatment. As the secondary manifestations of the disease disappear under treatment, the enlargement of the inguinal glands also subsides. When the induration in them persists after other symptoms have yielded to treatment, inunctions with the mercurial ointment or the oleate of mercury over the ganglia will often cause their reduction in size. Compression might also be resorted to in these cases with marked benefit.

Joseph Ransohoff.

[1] Rindfleisch: Pathol. Gewebelehre, p. 159.
[2] Jullien: Traité pratique de mal. vénér., 1879, p. 429.
[3] Dict. nouveau des sc. médicales, vol. v., p. 764.

[4] Grünfeld: Real-Encyclop., Bd. ii., p. 613.
[5] Centralblatt f. Harnk., 1897, p. 354.
[6] Art. Bubo, Quain's Dict.
[7] Ven. Dis., p. 479 (fourth edition).
[8] Rindfleisch: *Loc. cit.*, p. 172.

BUBO PLAGUE.—(Synonyms: The Pestilence, or Pest; the Black Death; the Plague of Egypt; the Oriental, Levantine, Indian, or Pali Plague [Máhámari]; Adeno-Nervous Fever, Typhus Pestilentialis, Malignant Polyadenitis, Pestis Bubonica, etc.)

Definition.—The bubo plague, or more briefly, the plague, is a disease which at times is widely disseminated, and which consists of a single paroxysm of acute, infectious, and contagious, febrile disorder. It is characterized clinically by a sudden onset, short course, great mortality, and, specifically, by the occurrence of carbuncles, ecchymoses, and petechiæ upon the general surface, and occasionally by gangrenous inflammation of the lungs, more commonly by the development of glandular swellings, tending to suppurate, in the inguinal and axillary regions and exceptionally elsewhere in the body. The plague is endemic in certain localities, notably those bordering on the eastern shore of the Mediterranean Sea and in the Oriental countries adjacent thereto. Occasionally it extends widely as an epidemic, especially along the great paths of commerce to other parts of the world, even to the Arctic zone, thus becoming pandemic. It is apt to prevail particularly during certain seasons of the year.

Discovery of the Specific Cause in the Bacillus Pestis.—The plague bacillus was discovered by Kitasato in an investigation of an outbreak at Hong-Kong made by direction of the Japanese Government and published in 1894 under the auspices of the University of Tokio. Yersin and Roux, by independent research, which was made almost coincidently with that of Kitasato, also discovered the same micro-organism. The plague bacillus is a short bacterium or coccobacillus, almost as broad as long, measuring about 2 μ in its greatest diameter. As the bacteriological characters of the plague micro-organism have been discussed in the article on *Bacteria*, in Vol. I., it will be necessary here merely to call attention to a few facts of especial interest from the clinical standpoint. This bacillus pestis enters the human body with great facility, and rapidly multiplies after its introduction. It is found generally in the contents of the alimentary canal, in the blood, in the interior of organs, and especially in lymphatic glands, and in the discharges from buboes. While possessing extreme virulence in its action upon the animal organization, its own resisting power to chemical disinfectants is feeble. Carbolic acid in weak solution (one per cent.), or even lime water, will render it innocuous. Experiments made recently in the laboratory of the United States Marine Hospital Service at Washington, D. C., have demonstrated the fact that it is easily destroyed by all of the ordinary disinfectants. It dies in four days, if kept at a dry heat of 60° C. (140° F.), or in half an hour if subjected to a temperature of 80° C. (176° F.), and in a few minutes if subjected to a heat of 100° C. (212° F.). On the other hand, it develops easily in many culture media at the ordinary temperature—18° to 22° C. (64.4° to 71.6° F.). It loses its virulence by drying, and retains its virulence only when subject to the action of moderate heat and moisture. Dr. Walter Wyman, Surgeon-General of the Marine Hospital Service, in a recent official report on the bubonic plague, from which this statement is taken, gives a succinct account of the disease as it has come under the notice of his department. As regards its causation, he says: "The presence of organic matter, animal or vegetable, and in a state of decomposition, would seem to furnish the most favorable nidus for its growth, which will account for its more prolonged existence in Oriental countries and the comparative rarity of its appearance in Europe since the existence of modern and improved hygienic conditions. This does not mean, however, as was maintained by some at the Venice conference, that filth and crowding are alone responsible for the disease. The malady is pre-eminently of bacterial origin, and wherever the microbe is found, there the plague is likely to develop. The length of its life, when exposed to favorable conditions outside of the human body, has an important bearing upon the quarantine measures necessary to be enforced, particularly with regard to merchandise from an infected port." From a number of experiments made to determine the temperature and time required to kill the bacillus outside of the human body (according to the report of the German Plague Commission as quoted by Bowhill), "the longest time that infected material as lint, wadding, earth, etc., remained active was eight days. Sputum, from patients affected with the pneumonic form, kept in a vessel plugged with cotton wool, was no longer virulent in sixteen days. In ordinary drinking water the bacilli die in three days, in sterilized water in eight days, and in sterilized bilge water in five days. The bacilli are killed by drying at ordinary room temperatures in four days, according to Bowhill. The bacillus of plague is found in the dust of infected houses and in the soil, which has been contaminated by discharges from the body. It is also found in the bodies of domestic animals and vermin which dwell in infected houses and which die in great numbers during an epidemic. It is believed that mice, rats, dogs, beetles, flies are important factors in communicating contagion. The results of the study of the flagellate parasite of the rat's blood, the *trypanosoma*, by Rabinowitsch and Kempner,* establish the fact that fleas are the active agents of communication of this form of hæmatozoon infection. It is probable, in a similar manner, that fleas, especially in the Orient, convey the plague bacillus, especially as dogs and rats are so commonly infected at an early stage of the epidemic. In a recent paper, Professor Galli-Valerio, of the University of Lusonne, combats the idea that the particular flea, which is parasitic in the rat, can be instrumental in conveying the infection of bubonic plague directly to man. In experiments made upon himself, he was unable to obtain any evidence that this flea (*Typhlopsylla musculi*) will remain upon the body of a man unless under compulsion, or that it will puncture the skin of man. Surgeon-General Sternberg, U. S. Army, in a recent article in which this reference is found, says that "he admits, however, the possibility that plague might be transmitted from man to man by the well-known domestic flea (Pulex irritans)." As plague bacilli have been found in the intestinal contents of the rat's flea, it is possible that this parasite may after all play an active and important part in disseminating the plague among the rats and other inferior animals, and also contribute its quota toward causing infection of house dust which mingles with food and drink of man.

Nosology and Clinical Forms.—The terms plague, pest, pestilence, the Black Death, la Grande Mortalité, and similar popular names have in the past been applied without discrimination to every form of epidemic disease attended by great mortality. In early times, therefore, epidemics of erysipelas, hemorrhagic or black measles, cerebro-spinal fever, typhus, and other infectious diseases, even leprosy, have been confused in the public mind and in the medical records with the bubo plague, and it is difficult, if not impossible, to declare at this late day, in some instances, exactly what form of infectious disease was responsible for the epidemic in question. By degrees, however, as knowledge of pathology and diagnosis increased, the term plague has, by exclusion, come to be understood as applying solely and only to the disease now under discussion. Therefore, whenever the word plague is used in this article it means the bubo plague, or malignant polyadenitis.

It has been observed and should be borne in mind that the clinical manifestations following infection with the plague bacillus may be modified to a certain extent by natural causes or attending circumstances, social as well as meteorological, so that the symptoms may not be identical in form in different countries or in different epidemics. Thus the black death, which ravaged Europe in the fourteenth century, presented features which, in the minds of some nosologists, create a doubt as to its really being an instance of the bubo plague. When we recall the sanitary, or rather horribly unsanitary condition of most European countries at that time, and the mode of living which then prevailed, we may find sufficient reason for some modification of the symptoms of the plague as known at the present day. Dr. J. C. Wilson,* from whose able summary of the literature of the plague this remark was extracted, also states that a like difference of opinion exists in regard to the relationship between the Indian or Pali plague, which has from time to time prevailed in Northwestern India during the present century, and the true plague. The black death of the fourteenth century and the Pali plague, though presenting many of the characteristics of bubo plague, differ from it, while they resemble each other in one important particular. Among the earlier and more common symptoms of note are those dependent upon gangrenous inflammation of the lungs, a lesion, according to Hirsch, extremely rare in bubo plague. This author informs us that recent observations have fully confirmed the early opinion that the Pali plague differs from that of the Levant chiefly in this modification, and cites Pearson and Francis as saying of the former disease that "the collective symptoms are more like those of plague than of any other known disease. . . . We believe it to be in all essential particulars identical with the plague of Egypt."

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* Zeit. für Hygiene u. Infektionskrank., 1899, xxxi., p. 251, and Journal Amer. Med. Assn., April 28th, 1900.

Clinically, the cases of plague have been grouped according to their severity into three classes: (1) The typical, ordinary, or grave cases. (2) The fulminating cases. (3) The abortive, or larval, cases.

Adopting the usual basis of classification by systematic writers, which is more in accordance with the semeiology and pathology, we have: 1. The bubonic or ganglionic form. 2. The pneumonic form. 3. The septicæmic form.

"Of these forms," says Wyman, "the bubonic is the most common, the pneumonic the most fatal. The method of infection—that is to say, the point of entrance of the specific microbe—is a point still under active discussion, and is different not only for the various types and forms given, but also varies in different countries and in different sections of the same country. For example, in Hong-Kong, where the natives as a rule go barefooted, infection, in a large number of cases, has been traced to abrasions and wounds of the lower extremities. In India, some covering or protection foı the foot is usually worn, but the natives suffer from the bites of insects and vermin; consequently the point of entrance of the infection has been largely upon the hands and arms. Infection through the intestinal tract, while admitted, is as yet largely unexplained; for in spite of the assertions of Wilm, some breach of continuity would seem to be necessary for the entrance of the micro-organism. As a rule, a small red spot marks the point of infection; this becomes successively a vesicle and a pustule, and in the ganglionic form, and in a large proportion of cases, a general redness, or a series of vesicles, marks the passage of the infection along a lymphatic tract or channel. These vesicles have been of very frequent occurrence in the Bombay epidemic."

Essential Character of the Disease.—At the present day, plague is classed as a contagious miasmatic disease (Liebermeister) in a group with enteric fever, cholera, epidemic dysentery, etc. Up to the seventeenth century, the plague was commonly ascribed to moral causes, as a visitation of the wrath of an offended higher power upon the people for their sins, or to some evil combination of the stars, which were supposed to preside over the health of man. It was Sydenham who first clearly pointed out the true nature of the disease and showed that it was like other disorders and therefore due to purely natural causes. In opposition to the ancient belief that the epidemic was produced by some atmospheric or meteorological condition, or hypothetical "epidemic constitution of the atmosphere," Sydenham acutely observed that infection either from a sick person or some fomites or infected clothing is an essential prerequisite to the outbreak. While maintaining the teachings of experience that changes of the atmosphere and the season of the year do affect the prevalence of epidemic diseases, and that, in point of fact, the plague itself is more apt to prevail in summer and the early fall in the temperate zone, and to diminish to a minimum in the winter, he insists that still something more is necessary. In his medical observations (chap. ii.) on the "Pestilential Fever and the Plague of the Years 1665 and 1666 as it Appeared in London," he remarks:* "I am far from denying that a statement made by several authors, as to the plague having originated during periods of the year other than that mentioned above, may be possible. The fact, however, is a rare one, and when it takes place, the ravages of the disease are less. . . . On the other hand, I have grave suspicions that the mere atmospheric condition, however much λοιμώδης (*loimodes*, Gr., from *loimo*, the plague), is by no means sufficient in and of itself to originate plague. Either the disease itself must continue to survive in some secret quarter, or else, either from some *fomes*, or from the introduction from pestilential localities of an infected person, it must have become extended. And, even in these cases, it cannot become epidemic, except with the conditions of a favorable atmospheric diathesis. Except upon this principle, I cannot comprehend how, of two towns near each other, and under the same conditions of climate, the one shall be grievously afflicted with the plague, the other be wholly free, and that by merely cutting off all communication between itself and the place infected. Yet this was done not many years ago, through the care and foresight of the Grand Duke Ferdinand II., who effectually stopped on the borders of Tuscany a plague that devastated nearly the whole of the remaining parts of Italy."

Former Epidemics.—It is probable that epidemics of plague raged prior to the dawn of history, since as far back as our records extend we meet with references to pestilences, which recall the features of this form of epidemic disease. Manetho, an Egyptian historian, who lived at the beginning of the third century B.C., described pestilences, resembling the plague, which ravaged the valley of the Nile during the reign of the most ancient Egyptian kings. The early Jewish writers of the Bible refer repeatedly to the plague as a visitation upon the people for various acts of disobedience. Zechariah (xiv. 12–18) refers, about 487 B.C., to a plague that shall "smite all the people who have fought against Jerusalem," and "the heathen that come not up to keep the Feast of Tabernacles"; but the description given does not agree with the clinical features of bubonic plague. "Their flesh shall consume away while they stand upon their feet, and their eyes shall consume away in their holes, and their tongue shall consume away in their mouths," which rather applies to an affection like leprosy than to an epidemic disease such as the plague. In fact, in Leviticus, the "plague of leprosy" receives a great deal of attention. Some confusion has arisen from the fact that the Hebrew word translated plague means "a smiting," and was applied to various kinds of disease without much discrimination, with either moral or medical signification. It has been recently stated,† with much appearance of probability, however, that the bubo plague is referred to in the Bible at a date more than eight hundred years previous to the hitherto accepted record, which has generally been dated 300 B.C. Drs. F. Tidswell and J. A. Dick, in a communication presented to the Royal Society of New South Wales, have furnished evidence to show that the plague of 1141 B.C., described in the First Book of Samuel (chaps. iv.–vi.), was true bubo plague. After the Philistines had captured the Ark of the Covenant, and taken it to Ashdod, severe illness broke out among the people. "The hand of the Lord was heavy upon them of Ashdod, and he destroyed them and smote them with emerods." The Ark was afterward taken to Ekron, and here again we are told, "There was a deadly destruction throughout all the city, . . . and the men that died not were smitten with the emerods, and the cry of the city went up to heaven." The word "emerod," on account of similarity of spelling and sound, has usually been taken to mean hemorrhoids, but in the Revised Version of the Old Testament it is stated to mean "tumor," or "plague boil." The epidemic in Philistia occurred at the time of the regular plague season, and mice are mentioned in connection with it, which furnishes additional evidence that the epidemic was plague, for a connection has been clearly established between the death of rats and the plague, at Bombay and elsewhere, as has been already mentioned.

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* "The Plague." Pepper's "System of Practical Medicine," by American Authors, Philadelphia, 1885, p. 771.

* Sydenham Society's edition of the works of Thomas Sydenham, M.D., London, 1848, p. 101.

† Nature, March 22d, 1900.

Thucydides described a plague which prevailed in Athens from 439 to 432 B.C., and reappeared again eighteen months later. Acron of Crotona is said to have dissipated the cause of this plague by means of fires kept burning in the streets. During this epidemic, Athens lost more than one-third of its population. Thucydides himself suffered with the disease, and Hippocrates noted it, in the aphorism, "All fevers complicated with buboes are bad, except ephemerals." Dr. Adams, the translator of the Sydenham Society's English edition of Hippocrates, mentions the curious omission of all allusion to the contagiousness of certain diseases by Hippocrates, although his contemporary, Thucydides, in describing the plague, expresses himself in such terms as put it beyond doubt that he regarded the disease as being of a contagious nature. Not the least reference to contagion, in any shape, is to be found in any of the Hippocratic treatises.

Plague was epidemic in Libya, according to Rufus of Ephesus, in the third century B.C. The great plague reported by Livy, who died 221 B.C., is said to have destroyed a million persons in Africa; no records remain, however, of its extension to Europe. The earliest account in the Christian era of a great epidemic of the plague is furnished by Procopius. This outbreak began in the year 542 in Egypt, from whence it extended to Palestine, Syria, and Persia; it then passed from Asia Minor into Europe, at Constantinople, where it carried off ten thousand victims in one day (543 A.D.). From this as a centre the plague, becoming pandemic, spread in all directions, carrying death and destruction in its train. It is estimated that shortly before the close of the sixth century fifty per cent. of the inhabitants of the Eastern empire had perished, either directly from the plague or indirectly from the destitution and disturbance of society incident upon the plague. This epidemic, known as the Justinian plague, is of historical importance, as the disease at this time established itself in Europe, where it maintained a foothold for more than a thousand years. In the seventh century it appeared in England. The fourteenth century again witnessed the spread of the plague from the East, whence it extended throughout Armenia, Asia Minor, Egypt, Northern Africa, and nearly the whole of Europe. In all the epidemics of this century, Hecker calculates that one-fourth of the entire population of Europe, or 25,000,000 persons, perished. R. B. Anderson ("America Not Discovered by Columbus") says that "the black plague reduced the population of Norway alone from 2,000,000 to 300,000." It was during this period that Venice took measures to check the spread of the plague and appointed three guardians of the public health charged with this duty. In 1403 there was opened the first quarantine establishment on a small island adjacent to Venice. In the fifteenth century the plague recurred frequently in nearly every part of Europe, the mortality being not less than 40,000. During the sixteenth century the epidemic continued. In 1572 50,000 died at Lyons, in 1576 Venice lost 70,000. In the seventeenth century occurred the great plague of London (1664 and 1665) of which Sydenham, Defoe, and Mr. Pepys wrote. It is said to have proved fatal to one-third of the population, or more than 68,000 inhabitants of this metropolis. In 1656 it raged for five months in Naples, causing the death of 300,000 people. This, however, was the last extensive outbreak of the plague in Italy, as the great epidemic in London in 1665 was its final appearance in England previous to the occurrence of some isolated cases last year. In France, it still lingered in the provinces until 1668, although malignant epidemics had ceased several years before. In the early part of the eighteenth century two outbreaks occurred in Europe. The first spread from Turkey, through Hungary, to Russia, Norway, and Sweden, and thence along the Baltic to the Netherlands, coming to an end in 1714. Six years later, the last great outbreak on the European continent took place. It prevailed in Marseilles in virulent form, costing the lives of from 40,000 to 60,000 people in this one city alone. In 1721 it appeared in Toulon and spread over Provence, carrying off 87,000 out of a population of less than three times that number. In 1743 Sicily was attacked, the mortality at Messina being between 40,000 and 50,000. In 1771 nearly a quarter of the population of Moscow died of it, or more than 50,000 people. In the century just ended the plague has been confined principally to the East, although during the second and third decades repeated outbreaks occurred in the Balkan peninsula and the regions bordering on the lower Danube and the Black Sea. In 1815 it appeared on the Eastern coast of Italy, but was restricted to a small district. This was its final appearance in that country. A small epidemic was observed in Greece in 1828. The plague appeared in Malta in 1813, and in 1816 it extended to certain of the Ionian islands. Again, in 1820, the plague appeared at Majorca, whither it had been brought from the Barbary coast. Owing to favorable conditions on the coast of Northern Africa the plague has repeatedly appeared at Tunis and Algiers, and has generally shown a tendency to linger. The plague of 1784 lasted for fifteen years. Between the years 1816 and 1821 the disease again manifested itself in these cities, and again in epidemic form in 1836 and 1837. In 1835 there was an outbreak of such degree of severity in Cairo that the deaths equalled in number the entire adult population. Subsequent to this it ceased to prevail to any extent in Africa. It disappeared from Asia Minor, Syria, and Palestine in 1843, and from Egypt in 1844. Reports of the presence of the plague from time to time were made from Dalmatia (1840), Constantinople (1841), Canary Islands (1852). Since 1850 the disease has oscillated now east, now west, between the Red Sea and the Pacific, in China, India, Arabia, Persia, Mesopotamia, Russia, Caspian Sea, Afghanistan, Tripoli. There have been since 1850 but nineteen years when it was not recorded in one or the other of these countries.

For a short period, near the middle of the last century, nothing was heard of the plague, and it seemed unlikely that there would be any repetition of the periods of extensive prevalence, or pandemics, which had characterized the disease in former times. It is true that after a season of great scarcity of food in the northwestern provinces of India, the plague appeared in 1815 and continued until 1821, reappearing in 1836, and again in 1837 in Pali, and that, according to Hirsch, it has never disappeared entirely from the southern slopes of the Himalayas since 1823, where it has raged at an altitude of 16,300 feet. Its ravages in these mountain districts have been so great that some settlements have been wholly destroyed. The last outbreak to occur on European soil was that of 1878 and 1879, upon the banks of the Volga. Tropical Africa has never suffered from the plague.

The Present Epidemic.—In 1892 the Chinese Government, in the course of some military operations, moved certain stores and materials by caravan, from Yunnan, which was the endemic focus of the disease, to Longtcheu. The disease made its appearance in the latter place in 1893, and was thence conveyed by trading junks to Canton and Hong-Kong, in which cities it was recognized as epidemic plague in 1894. From Hong-Kong it was conveyed by sea to Bombay, Kerachee, and Poonah. Wyman estimates that as a result of this epidemic outbreak there were 220,907 cases in Bombay presidency alone, with the enormous mortality of 164,083. It also prevailed in Calcutta, Amoy, Formosa, Alexandria, and the port of Kobe in Japan. In 1899, Nieuchwang, in China, was invaded, and the epidemic soon gained a foothold, the domestic animals dying in great numbers and infecting the surroundings and the soil. It again made its appearance in Europe in Oporto, Portugal, in August, 1899. Some not well-authenticated cases at Plymouth and Southampton, England, have been reported within the past few months by the public press as having occurred, but through the vigilance of the sanitary authorities the disease has not been able to extend its influence outside of the small area directly connected with the shipping. There has been noticed, however, at Southampton an epidemic among dogs which was so fatal and infectious that in a short time the town was nearly cleared of its canine population. From this source the disease has since spread to many other parts of England, and the epidemic is receiving much attention from the veterinary physicians.* In October, 1899, the plague appeared at Santos, Brazil. This outbreak, as noted by Wyman, marks an important epoch in plague literature, as furnishing the first recorded instance of the occurrence of the disease in the Western hemisphere. The outbreak occurred after the arrival of a ship from the infected port of Oporto, which lay alongside the dock in Santos, and within a short time there was an extensive mortality in July and September among rats, preceding the appearance of cases among human beings. On the 18th of November, 1899, the British steamship *J. W. Taylor*, from Santos, arrived at the quarantine station, New York, with two cases of bubo plague on board, and reported having lost one man at sea from the same disease. Owing to the prompt and effective action of the United States quarantine officials in disinfecting the ship and cargo, no spread of the disease occurred. A few suspicious cases in the Chinese quarter have occurred at San Francisco, Cal., but as the sanitary authorities were alert and took the necessary steps to control the disease, no communication from these cases has been observed.†

The recent acquisition of the Hawaiian Islands and the Philippines by the United States, among other advantages, has given us the rather questionable one of having the first veritable epidemic of plague in territory under our flag. In the latter part of December, 1899, plague broke out in the Chinese quarter of the city of Honolulu. As a result of the most vigorous measures for its extinction, including the application of the torch (with the unexpected result of the destruction of a large portion of the city), the deportation of the population from the infected quarter, and the establishment of a cordon preventing all communication between them and those outside, the epidemic has not spread, and as a result of thorough disinfection comparatively few cases have since occurred. The plague subsequently broke out with decided virulence among the filthy huts of the Chinese quarter of Manila. The military authorities, however, at once adopted active measures to prevent its spreading and to limit its course. The St. Petersburg plague board reports recently that bubo plague is prevalent in Assyr, Mecca, and Jeddah, and that, accordingly, last year's Mussulman pilgrimage to Mesopotamia was prohibited. A report from Major Blair D. Taylor, United States Army, in regard to the progress of plague in Honolulu, dated January 15th, 1900, states that up to that date there had been 34 cases, with 27 deaths. The following week there were 12 new cases and 6 deaths. Plague has disappeared from Kobe, Japan, but is active in Osaka, taking the form of a lung disease which proves very fatal. At the present time the epidemic of 1899–1900 seems to be on the decline in the East and has gained no foothold in Europe or America. General Wyman believes that, with the rigid application of the ordinary principles of sanitary science and with the means now at our disposal for the prophylaxis and cure of the malady, it seems extremely doubtful if the plague will ever secure a decided foothold in the United States.

Accidental Propagation.—Incidental to the recent outbreaks of the plague was the unfortunate communication of the disease to several physicians who were engaged in making bacteriological investigations. The Japanese Commissioner Aoyama, who accompanied Kitasato to Hong-Kong in 1894 by direction of the Japanese Government, contracted the disease by inoculation incurred during a post-mortem examination, but fortunately recovered, although one of his assistants died of disease contracted in the same manner. More recently, in 1898, the disease appeared in Vienna, in Professor Weichselbaum's institute, in which inoculation experiments were carried on upon guinea-pigs with material obtained from Bombay by a commission appointed by the Imperial Academy of Sciences of Vienna. Dr. Müller, who was a member of the commission, unfortunately fell a victim to his zeal for science, and a laboratory attendant named Barisch also died; two nurses were also attacked by the disease. The commission was successful in restricting the spread of the disease by adopting extremely active measures. The *Lancet* for October 29th, 1898, states that "as soon as the first case of plague was clearly recognized, the plague commission permanently closed Professor Weichselbaum's institute. All the animals used for experiments were killed and cremated, and the drains of the institute were disinfected. Dr. Nothnagel's clinic was cleared and disinfected, and the medical men and nurses belonging to it were isolated; the public were refused access to the General Hospital; all the medical men and the nursing staff were kept indoors, and some supposed febrile cases were transferred, from the institute and Professor Nothnagel's clinic, to the Infectious Hospital. Barisch's wife and brother were also admitted to the Infectious Hospital and received prophylactic treatment." These measures were completely successful, and abruptly terminated an outbreak that had startled the entire civilized world.

The Disease in Lower Animals, and their Agency in Spreading the Plague.—Concerning the matter of the part played by the lower animals in spreading the epidemic, our knowledge is still incomplete. Dr. Sticker, of the Vienna Commission, states that rats and mice are active carriers of the contagion. Preliminary experiments have shown that pigeons, hens, geese, and swine are insusceptible to the disease, while dogs, cats, sheep, goats, cows, and horses react to the infection by at least a transitory morbid state that ends in recovery. Monkeys are highly susceptible, especially the so-called sacred ape, and they may play an important part in the epidemics of India. Surgeon-General Sternberg, in reference to this subject, says: "We have learned that certain of the lower animals, including rats and mice, are very susceptible to infection, and that they play an important part in the propagation of the disease, also that the germs are found not only in the blood and in pus from suppurating buboes, but also in the discharges from the bowels of infected individuals. This being the case, it can readily be seen how important a strict sanitary police is in arresting the spread of an epidemic. As in other filth diseases in which the germ is present in the excreta of the sick, insects, and especially fleas and house flies, probably play an important part in the spread of the disease."*

Modifying and Predisposing Agencies.—Poverty, filth, physical and social wretchedness have become so generally recognized as predisposing causes to the plague that Cabiadis termed it *miseriæ morbus*, thus perpetuating a name given to the plague of 1665, in London, which was called "the poor's plague" (Wilson). The bad hygiene observed in the poorer class of dwellings, especially in tropical countries, not only favors the propagation of the epidemic by vermin, as already mentioned, but it also lowers the vital resistance of the individual and renders him more liable to infection than if he belonged to a grade higher in the social scale. The season of the year has some influence upon the development and course of the plague, but it has been remarked that the influence is not the same in different countries. The epidemics in London reached their height in midsummer and declined in the fall months. In Constantinople also the disease becomes dormant in winter and becomes active as the summer heat increases. In the epidemics of extreme Northern Europe, the disease has been equally prevalent in winter and in summer, while they lasted. Egypt and Mesopotamia, however, follow a different course; in Cairo the epidemics have always ceased upon the recurrence of the hot weather of June.

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* Journal of the Amer. Med. Assn., March 3d, 1900, p. 568.
† *Ibid.*, March 24th, 1900, p. 763.

* "History and Etiology of the Bubonic Plague," Philadelphia Med. Journ., April 7th, 1900.

A marshy soil is favorable to the spread of plague, repeated outbreaks having occurred in the valley of the Nile, the marshy regions of the lower Euphrates and along the Caspian and Black seas ; but dampness and low elevation are not essential, since it has flourished in the mountainous districts of Arabia and on the slopes of the Himalayas, at a great elevation. Both sexes and all ages are liable to the infection, although young adults furnish the greater number of victims. Depressing influences, especially debilitating diseases, increase the individual susceptibility. Occupation has little influence, although it has been observed that oil carriers, dealers in oils and fats, and, to a less degree, water carriers and bath attendants are less liable to contract the disease than others. It is noted by Dr. N. F. Arnold, U. S. N., that those inhabitants of Chinese cities in which epidemics are in progress who live in boats suffer little. This is probably due to the fact that communication between the rats and other animals inhabiting them and those of the land is not easy (*Philadelphia Med. Journ.*, April 7th, 1900, p. 789). The plague is to a certain extent self-protective; second attacks, if they occur, are of less severity than were the first.

Incubation Period.—The period of time which elapses between exposure to infection and the development of the disease is comparatively short. Prus, in a report drawn up for the French Academy of Medicine in 1844, declared that the plague had never shown itself among compromised persons after an isolation of eight days. It appears that from three to six days is about the rule. Cabiadis sets the incubation stage at three days, but occasionally it lasts only twenty-four hours. Hirsch, from observations on the Astrakhan epidemic, concluded that the average period was five days, very short or very long periods being seldom observed. Recent observations by Haffkine and Simond agree in showing that the incubatory period may be as short as twelve hours, but, on the other hand, that, in a number of cases observed in a detention camp, over six per cent. occurred as late as the ninth day, and 1.73 per cent. as late as the eleventh day. Wyman justly remarks that this point has an important bearing on quarantine measures at ports of arrival, for it does not bear out the theory that the period of incubation is such that all cases which are to occur will occur on the voyage, since a fair proportion of the cases developed in a period which exceeds the average duration of a trans-Atlantic passage in these days of fast ships.

Relative Danger of Propagation by Fomites and Merchandise.—With regard to the transmission of the disease by fomites and the dangers of spreading an epidemic by merchandise from an infected locality or from a ship having plague on board, it is fortunate that the vitality of the bacillus, apart from the animal body, is limited, its virulence being rapidly lost under conditions of heat, light, exposure to sun and to the air. In fact, this is in accord with every-day laboratory experience, where the greatest difficulty is found in keeping cultures of the plague bacillus in virulent condition. Wyman further says that "under ordinary conditions of laboratory growth, in the presence of uniform temperature, on favorable nutrient media, and kept from the influence of strong light, a culture of the plague bacillus, virulent to rabbits, will in two or three days so deteriorate that it is no longer pathogenic for the very susceptible mouse. Passage through the bodies of animals, repeated at short intervals, seems to be necessary to preserve the virulence of the bacillus. These conditions removed, its viability is short, and it either perishes altogether or becomes a saprophytic organism. It therefore would seem justifiable, in the present state of our knowledge, to assert that the relative danger from merchandise as a carrier of infection is slight, and that the greatest danger is to be apprehended from mild cases of the disease, unrecognized, little dangerous in themselves to the person having it, but as capable of spreading virulent contagion as is mild varioloid of communicating and imparting a virulent, fatal type of smallpox."

SYMPTOMS.—Of the three varieties or clinical forms of the plague which are usually recognized, (1) the bubonic, (2) the pneumonic, and (3) the septicæmic, the former is the most frequent and may be considered as the type. In cases of this ordinary grave or *bubonic form* we have present a highly contagious fever, setting in suddenly, attended with constipation, with a rapid, feeble pulse, with dizziness and delirium, with injected eyes, with a dry tongue, with noises in the ears and deafness, with defective urinary secretion, with starting of the tendons, with watchfulness or stupor, and with red patches and purple spots scattered over the surface of the body. Such is the graphic language used in describing the disease by Da Costa, to which he adds (as distinguishing it from typhus), nausea and vomiting, a pale face, an alarmed despairing look of the countenance, hæmoptysis, and, above all, the buboes and carbuncles in different parts of the body, and the clearing mind when they manifest themselves. Moreover, the disease is of much shorter duration than typhus. Death generally takes place between the third and the fifth day, or convalescence sets in on the sixth or the seventh day, or early in the second week. It may, however, be protracted by a long-continuing suppuration of buboes.

J. C. Wilson divides the course of the attack into four stages: (1) invasion, (2) intense fever, (3) fully developed localizations, (4) convalescence. The first stage is ushered in by a feeling of lassitude with pains in the loins and extremities. Extreme bodily debility, fulness and throbbing pain in the head, with dizziness and mental weakness, are complained of. The patient's expression is dull and stupid, and he responds but slowly or awkwardly to questions. His face is pale, eyes languid, his gait weak and staggering, as if inebriated. No distinct rigor is noticed, but shivering occurs, and nausea, vomiting, and diarrhœa may appear early. This stage begins suddenly and may last from a few hours to a day or more. It is followed by the febrile stage, which may be ushered in by a chill, more or less severe but commonly the latter. The lassitude and headache now become more marked. The temperature rises to 102°–104° F., or, exceptionally, to 107.6° F. The pulse is rapid, 120 to 130, the skin hot and dry, and the patient complains of fever and thirst. The eyes become sunken and injected as the case continues, the tongue is coated with a grayish pasty mass, the teeth and lips are covered with sordes, the vomiting often continues. Active and noisy delirium, with great restlessness, or mild delirium, tending to stupor or coma, now appears. Bloody crusts collect on lips and nostrils. The pulse grows feeble, small, often very irregular, the lips become bluish, the extremities cold, and there is impending collapse. The enlargement of glands may now be noticed, with tenderness and swelling of the superficial lymphatic vessels. A sudden fall of temperature, often to several degrees below the normal, now occurs, frequently attended by a profuse, strong-smelling sweat. The pulse falls to 100 or below, and the mind clears.

The third stage is characterized by suppuration and great enlargement of the glands of the groin, or upper part of the thighs, less frequently in the axilla or near the angle of the jaw. As this usually does not occur in fatal cases, suppuration is looked upon as favorable. The buboes may appear as early as the second day, sometimes as late as the fifth day, exceptionally they are absent altogether. Carbuncles, though less common than buboes, are also likely to appear at this stage, especially on the legs, buttocks, or the back of the neck, but they are not necessarily fatal, as the slough may soon separate, the gangrene being of limited extent. Boils also are occasionally seen. The appearance of petechiæ is regarded as unfavorable; they may be detected only in the neighborhood of the buboes, or may appear in great numbers all over the body, giving the cadaver a livid hue (from which character the name black death probably was derived). Extensive ecchymoses may also appear just before death.

The fourth stage, that of convalescence, begins about from the sixth to the tenth day, and may be delayed by prolonged suppuration or by relapses. Among special features to be noted among this class of cases is the matter rejected from the stomach, which at first is simply gastric mucus with bile or later a coffee-colored fluid; hæmatemesis may occur. Bleedings from the nose, lungs, bowels, vagina, and bladder have also been observed. Such cases generally terminate fatally. The urine may contain albumin and blood, hyaline and granular casts are commonly found; it also frequently contains indican; the quantity voided is diminished or suppressed in grave cases. The temperature record is not characteristic: it remains at 102–103.5° F. for about three days; it then becomes nearly normal or subnormal, and may rise again, if septic processes supervene. The blood becomes leucocythæmic, but the red cells are not diminished in number. The blood contains the plague bacillus, in the great majority of cases. In some, especially early in the epidemic, the disease progresses with such intensity and rapidity that the characteristic symptoms have not time to develop; the whole duration of the attack is only a few hours. In this, which is called the fulminant form, convulsions and coma, with the rapid formation of petechiæ and vibices, precede the fatal termination. This form is most likely to occur in the aged.

The *pneumonic form* of plague occurs principally in India. Whereas, in the ordinary bubonic form, the infection apparently enters the body by means of some wound, abrasion, or bite of an insect, in this form the lungs appear to be the door of entrance. Pneumonic plague cases occurring during an ordinary epidemic, according to Harris and Arnold,* are all fatal, usually within the first four days, and without any other symptoms than fever, cough, bloody expectoration, pain in the chest, and the symptoms of the digestive and circulatory disturbance noted above.

The *pneumonic form* was prominent in the epidemic known as the black death. Dr. Calmette reports that he has observed it in the recent epidemic in the city of Oporto, Portugal, and that in pulmonary plague there are no buboes, but the cases are marked at the outset by a profound depression of the vital powers, by violent vomiting, cadaveric paleness, a rapidly failing pulse, and death within a few hours. W. C. Hossack, in the *British Medical Journal*, February 10th, 1900, described a peculiar form of plague pneumonia. Its onset is insidious, and at the end of five or ten days the symptoms may be very little marked, while the physical signs are scarcely recognizable. Intelligence is unaffected, head symptoms are wanting, and death, when it comes, is apt to be quite unexpected. The pulse is the most important diagnostic point; it is disproportionately quick and feeble. As a rule, there are no enlarged glands, unless late in the disease, and every case proves fatal. They are recognized, by Hossack, as a form of pneumonic plague. What has been termed the *septicæmic form* is regarded, by Sternberg and others, as a secondary phenomenon, which occurs only in very severe and usually fatal cases. Arnold says that a bare ten per cent. of all cases will reach the septicæmic stage. Such cases as present no buboes have probably received infection either through the respiratory, genito-urinary, or digestive passages. The same observer reports having seen several cases that presented conclusive evidence of the last mode of inoculation.

In cases of the ordinary type an early symptom is the presence of pain and tenderness on pressure in the inguinal region. The onset is often marked by convulsive tremor or shivering, without sensation of cold, a staggering gait, confusion of mind, dizziness and headache, with a dull expression of countenance, great prostration, and rapid appearance of typhoid state. In children, cervical adenitis is more common than inguinal.

From personal observation of the plague in London in 1665 and 1666, Dr. Sydenham furnished the following clinical description:

"The first attack is almost invariably ushered in by chills and rigors (such being also the accession of intermittent fevers), which are followed by violent vomiting, by pain in the region of the stomach, like that of the pressure of a screw, burning fever, and its usual crowd of concurrent symptoms. These affect the patient without intermission, until either death itself or else the favorable breaking out of buboes or of parotid abscesses. Hereby the morbific matter becomes eliminated, and relieves them from the appalling crises.

"Occasionally it happens that the disease lights upon the patient without any premonitory signs of fever whatsoever, so that, even whilst engaged in his common business, a man may be suddenly struck down,—an eruption of crimson blotches being the only forerunner of his quickly coming death. It is important, however, to remark that death, thus sudden, rarely happens, except during the beginning of epidemics of more than ordinary severity. In years when the disease has been sporadic, and during its remissions and decline, they have never been observed. It happens also that at times tumors may break out without either fever or any other important symptom as their precursors; although I suspect, for my own part, that chills or shivers, in some slight degree or other, and more or less perceptible, invariably precede. Those to whom this happens may walk about in public as usual, and attend to the common duties of life like healthy men, taking no thought of regimen."

The German National Board of Health has issued recently a circular to physicians, containing official instructions regarding the plague, from which the following graphic description is extracted:*

The outbreak of the disease proper is preceded by lassitude, depression, pains in the lumbar region, increased thirst, and diminished appetite. It frequently begins quite suddenly. Stinging, burning, or dull pains at the point which corresponds then or later to the bubo, the inflammation of the glands or the pneumonia, may be the first manifestations of the disease, soon accompanied by chilliness amounting to a rigor, and consecutive fever. The latter may exist for several hours or days before the local manifestations develop. The commencement of the disease is almost invariably accompanied by a sensation of vertigo in the head, which may increase to resemble a severe intoxication, with the external indications of extreme stupor, and loss of control over the limbs, and then pass away. Nausea or vomiting frequently accompanies the vertigo. When the patient reaches the physician the clinical picture in severe cases is usually fully developed. The patient produces the impression of a drunken man: the vacant stare; the face bloated, flabby, expressionless; the extremely bloodshot eyes; the thick, stammering speech, and uncertain, staggering gait. This impression is enhanced by the abrasions and bumps caused by the stumbles and falls of the patient. The tongue looks as if it were whitewashed with lime, or is occasionally red and knobby like a raspberry. The skin is dry over the entire body and burning hot, or it is merely hot on the face and trunk, while the pulseless limbs are already cold and covered with a sticky sweat. The respiration is labored or sighing; the heart beat is much accelerated; the arteries are relaxed; the radial pulse is dicrotic, full or already thready, near extinction, while the heart beat is still vigorous. Put to bed, the patient lies dormant in extreme exhaustion, whispers low or talks confusedly to himself or tosses restlessly on the bed with loud delirious ravings, or, if he is not prevented by the attendant or fastened to the bed, gets up and wanders restlessly about in a wild frenzy, and makes efforts to escape. With careful scrutiny it is possible to detect the local disease focus even in the first hours, and thus approach the correct diagnosis. A freshly swollen gland and a pustule on the skin are the indications of commencing inflammation of the lungs, and belong to the developed clinical picture of the plague, which can thus appear as gland plague, skin plague, or lung plague. Plague of the alimentary canal has hitherto been established only in animals. The gland plague or bubo usually appears in the inguinal region, but also frequently in the axilla and in the neck, especially with children. In a few cases it has been noted on the back of the head, on the elbow, the popliteal space, the anterior or posterior ear glands, the hyoid glands, etc. Frequently the superficial glands are only slightly inflamed; the disease process seems to have jumped them and affected the deeper glands, the second or third class glands, which develop into buboes. For instance, the femoral glands may be unaffected, while a large iliac or lumbar bubo may be palpated like an appendicular tumor through the abdominal wall; or a cervical gland may be only slightly swollen, while an area of dulness in the clavicular region and symptoms of compression in the cervical organs may reveal the formation of a bubo in the upper portion of the thoracic cavity. The separate enlarged glands can be distinctly palpated in the bubo, or the inflammation of the interstitial tissue may have bound them into a thick bunch which can only be vaguely distinguished from the surrounding tissues, and is frequently surrounded by doughy œdema extending far around and involving the skin. The sensibility of the bubo to pressure is usually much more than the spontaneous pain, so that the patient, by favoring the bubo by the position of the limb, experiences no pain. A small bubo is frequently not even noticed by the patient and his attendants, so that every gland that can be reached should be carefully and repeatedly investigated by the physician. Plague pustule and carbuncle are rare in comparison to the bubo. They begin with a small spot like a flea's bite anywhere on the body. The spot smarts sharply and soon develops into a larger or smaller blister with a cloudy fluid. The pustule either stops at this stage, or the subjacent tissues harden and soon become transformed into a deep carbuncle, progressing to a gangrenous ulcer. Inflamed lymph vessels frequently lead from the pustule to the nearest cluster of glands, and a bubo may then develop in them. A bubo may also develop in the vicinity of a carbuncle. Buboes, pustules, and pneumonia may appear from the first, at the commencement of the disease, sometimes before the fever, or they may become evident a few hours or days afterward, seldom later than the third day. In all forms of the plague the early weakness of the heart is noticeable. In all, symptoms of irritation in the alimentary canal are evident at first, with sensitiveness to pressure in the upper abdomen and cæcal region, violent vomiting, later also the passage of black fæcal masses. With considerable regularity there have also been observed a slight degree of tympanites; a soft, palpable, or percussionable swelling of the spleen, and traces of nucleo-albumin and serum-albumin in the urine. Vomiting of blood or blood in the urine is rarer. A diphtheritic affection of the tonsils is frequently noted early. There is almost constantly more or less conjunctivitis, which is frequently and rapidly complicated with keratitis and may lead to the complete suppuration of the eye. Punctated or striped hemorrhages in the skin and mucous membranes have been noted with varying frequency in different epidemics. In the course of the disease the lymph vessels beneath the buboes may become involved in the inflammation, and new buboes may develop elsewhere in the body.

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* "Bubonic Plague with Clinical Notes," Philadelphia Med. Journ., April 7th, 1900.

* Münchener med. Woch., January 2d, and Journal Am. Med. Assn., February 3d, 1900.

Mortality and Prognosis.—There is no other epidemic disease which owns a mortality rate so high as this. It has been already intimated that the virulence and prognosis of the plague are influenced by social and especially sanitary conditions in the community visited, and are also affected by the season of the year. As in other infectious diseases, cases exceptionally occur of very mild form, and in which the incubation stage may be unduly prolonged, these cases being important factors in disseminating the epidemic, although scarcely sick themselves. Others occur which are overwhelmed with the poison and die in a few hours. The mortality of the recent epidemic in China has been stated to be as high as 98 per cent.; that in India is 75 per cent. among natives; among Europeans it is said by Arnold to have never exceeded 60 per cent., and is usually much less. The Marine Hospital Service's issue for December 22d of its Public Health Reports gives some startling figures of the mortality of the present outbreak up to August 11th, 1899; namely, to mention only a few, that there had been in the Belgaum district 29,300 cases, with 22,042 deaths; in the Dharwar district 38,754 cases, with 31,307 deaths; and in the Nassik district 20,162 cases, with 15,480 deaths. The septicæmic and pneumonic forms are most fatal. If the necrotic material in the buboes makes its way through the overlying tissues and skin and evacuates itself, the patient's chances of recovery are generally admitted to be improved. If, on the other hand, the material in the buboes becomes diffused into the tissues, and is not evacuated, death from septicæmia quickly follows. The prognosis is greatly improved if modern sanitary and therapeutic measures are available and are early instituted.

Diagnosis.—The clinical features which distinguish the plague have just been considered. Although typical, fully developed cases could scarcely escape recognition, it is important for the protection of the community that the diagnosis should be made at the earliest possible moment. Suspicion of impending danger may be aroused by the occurrence of a great mortality among rats and mice; it has been observed that rats sometimes leave a locality in great numbers before the plague manifests itself in man. There may also be unusual mortality among domestic animals. A bacteriologic examination of these animals might thus give early information of the presence of the plague bacillus and anticipate the outbreak in man. In the human subject errors may be made in the milder cases of the bubonic form and in the pulmonic and septicæmic forms, but a bacteriologic examination properly carried out will clear up the diagnosis. The method pursued by Harris and Arnold is, in the bubonic form, to open a gland involved, under due antiseptic precautions, and plant some of the contents on any ordinary culture medium. Cover-slip preparations are also at once made, stained, and subjected to microscopic examination. In most cases, the latter procedure will at once determine the true nature of the case, as in addition to the morphologic characters of the bacilli their very number serves to distinguish them, for in no other disease are so many bacteria present. In the septicæmic form the blood should be examined in the same manner, and, if the bacilli are not found in the cover-slip preparations, they will develop in the culture. An examination of the sputum in plague pneumonia is at once sufficient to place the diagnosis beyond all doubt, as this material always contains the bacilli in great numbers—oftentimes in pure culture.

Morbid Anatomy and Histology. — Post mortem rigidity and lividity appear early. The temperature often increases after death (108° F. in some instances). Petechiæ usually, and carbuncles occasionally, are observed. In about half the cases, the *lymph nodes* of the groin first show the disease; in the remaining half, the axilla is affected in about fifty per cent. The superficial nodes appear to be first affected, but the disease quickly extends to the entire chain of glands to which the one first affected belongs. All the other lymph nodes of the body may be invaded, but especially those of the mouth, throat, intestines, and mesentery. The tissues around the nodes are softer and may show hemorrhagic foci. The nodes, or lymph glands, are very much increased in size. On section, the node substance is quite firm if the process is recent, or the contents may be semi fluid and mucilaginous, the material resembling lard. The cut surfaces often present a grayish, red color, with darker areas of hemorrhage, or the entire contents are of a dark red color. Other glands in distant portions of the body are enlarged, but do not present any hemorrhagic foci, except in cases of relapse. Around the nodes the tissues are swollen, the blood-vessels are engorged and contain pest bacilli; these are not found, however, in the tissues or lymphatics, although the latter are distended with lymphoid cells. Unless the necrotic process extends through the capsule, the tissues show no other change. Harris and Arnold found that in those instances in which the node has just been attacked, or in which the disease is of a mild character, there is evident increase in the number of cells within them, the vessels are dilated, and the lymphatic channels contain many bacilli. In advanced cases, no differentiation is possible; all the gland contents now consist of a finely granular material, which is colored pink when stained by hæmatin and eosin, or by the method of Van Gieson. Intermingled with this granular material there are quite a number of cells and some cellular débris. If the section be stained by the toluidin blue and glycerin-ether method, or by toluidin blue followed by eosin, this granular material is found to consist of countless myriads of pest bacilli, they constituting, in many instances, more than one-half of the entire contents of the node. The same authors insist upon the importance of the presence of mast cells, as they have never seen them in any other lesions of the lymph nodes. It is suggested that their function is to elaborate an antitoxin, as they never appear to be phagocytic, like the hyaline cells, but it was observed that around many of the mast cells there is a zone in which no bacilli are seen. There are also a few plasma cells and a few polymorphonuclear leucocytes. When the gland softens and breaks down, it is due to a process analogous to cheesy degeneration of tubercles; therefore it is obviously wrong to speak of the process as a primarily suppurative one. If, however, any of the organisms of suppuration subsequently reach the diseased area, or a mixed infection occurs, a true suppuration will ensue. Lymph nodes, in parts of the body at a distance from the original foci of the disease, show only macroscopic swelling and a somewhat darker color than is normal. On microscopic examination, the cells of which the nodes are composed are found to be apparently somewhat increased and the blood-vessels dilated. In severer cases, and in relapses, these vessels usually contain bacilli, but they are not found in the gland substance ordinarily.

Lungs.—The plague causes broncho-pneumonia, but more of the lung tissue is involved than is commonly the case in the ordinary forms of this disease. There is occasionally observed a fibrinous pleuritis with the pneumonia.

Spleen.—The spleen is large, dark colored, and soft. There are numerous hemorrhagic areas in its substance. Its vessels are greatly dilated. Many of the cells show degenerative changes. This organ always contains the bacilli, often in great numbers.

The *Kidneys* may be either somewhat enlarged or normal in size. There is hyperæmia, with areas of hemorrhage; especially between the Malpighian pyramids. The capsule is easily removed and the cortex is thickened and quite friable. The cortical cells are granular and many have degenerated and lost their nuclei. Hyaline substance resembling that found in the normal thyroid tubules is found in the uriniferous tubules. Areas of hemorrhage are occasionally seen between the collecting tubules, but there is no evidence of nephritis. In all the blood-vessels (which are enormously dilated), both in the Malpighian bodies and elsewhere, are found numerous pest bacilli.

The *Liver* is somewhat darker in color than normal, owing to hyperæmia and dilatation of capillaries. The liver cells show signs of degeneration and are irregular in form and swollen, with disappearance of the nuclei in many.

Intestines and Stomach show hemorrhagic foci and the lymph nodes are enlarged.

The *Brain and its membranes* are congested, and, rarely, fibrinous meningitis, or meningo-encephalitis, is met with. This condition of the brain is more often found in cases of the fulminant form in which death occurs within a few hours after inoculation.

The *hemorrhages* found in the various organs, according to the same authorities, are not caused by the mere presence of the bacilli, but they are the effects of a poison or poisons produced by bacilli. The instance is given, which was reported by the German Pest Commission, of a woman suffering with the pest who gave birth to a dead child, and although its body was entirely free of the bacilli, the hemorrhages were very numerous in its organs. The leucocytosis, which is so constant in the plague, may be frequently made out by sections of the tissues—the white cells being evidently increased in the blood that is present in the blood-vessels. A mixed infection frequently occurs: streptococci, diplococci, and different varieties of staphylococci may be found in various lesions or structures; generally, however, they appear late, or in the agonal period, and in such cases do not influence the result to any material extent. It is probable, however, that when recovery takes place they are active in causing eruptive diseases of the skin and prolonged suppurations of glands and carbuncles. Paralyses of certain muscles result from the occurrence of hemorrhages into the meninges and spinal cord.

Treatment.—At the present day attention is particularly concentrated upon the use of Haffkine's prophylactic and Yersin's anti-pest serums. The best recent authorities appear to be agreed as to the great value of these agents. It is understood that, as Wyman insists, it is necessary to draw a sharply defined line between the serum therapy and serum prophylaxis of a disease. In the case of plague the difference is not merely one of degree but of kind. The serum which may be successful in protecting against the plague may be powerless to cure it when once the disease has manifested itself. For the cure of plague, according to Wyman, there is at present but one accredited remedy, viz.: the curative or antitoxic "anti-pest" serum of Yersin and Roux.

The preparation of the Yersin serum is, in brief, as follows: Horses are treated with progressively increasing doses of the toxins of plague, prepared by subjecting virulent bouillon cultures of the B. pestis to a degree of heat which insures their sterilization. These injections at first have a very profound effect upon the horse, but in time a certain immunity is conferred, and his blood serum is found to have a very decided effect in preventing the infection of animals when these are subjected to inoculations of cultures of the organism after the usual laboratory methods. Usually the process does not stop here, but is carried on to the production of true anti-pest serum, preventive and curative, whose further preparation is as follows: When reaction to the increasing doses of toxin has practically ceased, toxins of the same nature are administered intraperitoneally and intravenously, and these are supplemented by the intravenous injection of toxins prepared with a special view to rendering soluble the toxin which is enveloped in the dead bacterial body. If necessary, this is supplemented by the intravenous injection of live bouillon cultures, and bleedings are practised and experiments made with the serum both against living, virulent cultures and against the precipitated toxins of the organism. When the serum has reached a point of strength when a dose of $\frac{1}{10}$ c.c. will protect a mouse of 25 gm. weight against living cultures and a three times mortal dose of toxin, the serum is considered to have acquired full antitoxic power, and is not only protective or prophylactic, but also antitoxic or curative.

A French commission, after an investigation made upon mice, monkeys, and human beings, during the epidemic in Oporto, reported that the value of the anti-pest serum is incontestable. In cases treated with it the mortality was only fourteen per cent., while in those not so treated it was at least seventy per cent. These cases were of the pneumonic form. When exposure to the plague infection continues, it is recommended by Roux that these inoculations should be repeated every thirty-five to forty days, but the reports of Simond show that they should be practised more frequently, viz., every fourteen or twenty-one days. It should always be borne in mind that these inoculations do not in any way take the place of general hygienic measures. The technique is thus given by Wyman:

General Technique.—The injection should be administered in the subcutaneous connective tissue of the flank, the abdomen, or the back, and should be practised under the usual antiseptic precautions. The region where the remedy is to be injected should be washed with a solution of carbolic acid (five per cent.) or solution of mercuric chloride (1 to 1,000). A large antitoxin syringe should, if possible, be employed, and before use it should be nearly filled with cold water and then submerged in water which should be brought to a full boil and maintained at that temperature for fifteen minutes. Having been emptied, it should be allowed to cool before being filled with the serum, as heat has an injurious action on the remedy, and the syringe may be clogged by the coagulation of albumen. In the absence of an antitoxin syringe, an ordinary hypodermic syringe may be employed in its stead, care being taken as to the sterilization as above, and, the syringe having been filled and emptied, the remainder of the dose determined upon may be administered without removing the needle by detaching-the syringe and filling its barrel the requisite number of times, the syringe being screwed or otherwise joined to the needle *in situ.* This obviates the necessity for multiple punctures, always disagreeable, and is an important point in the treatment of children.

(*a*) *Administration for Prophylactic Purposes.*—When a case of plague manifests itself in a house or on board ship, 10 c.c. of the serum may be administered to all persons exposed to the contagion. The injection is not accompanied by any inconvenient or disagreeable after-effects. It should be repeated in ten days in order to prolong the immunity, and in a badly infected locality the injections should be repeated several times.

(*b*) *Administration for Curative Purposes*.—The curative action of the serum is the more efficient the earlier in the disease the injection is practised. Large doses should be administered, 30 to 50 c.c., rather than smaller doses successively administered. Under the influence of the serum the fever decreases and the swelling of the glands (the buboes) rapidly diminishes. If this amelioration is not produced promptly, a second and even a third dose should be administered until the fever and the general and local symptoms disappear. This is important, for so long as the bubo remains, especially if suppuration supervenes, the patient is liable to secondary infections.

The Haffkine prophylactic is intended solely for prophylactic purposes, and is not to be used after a person has already been exposed to the infection. Under antiseptic measures, the dose of 1 c.c. is administered hypodermically, and, when the constitutional reaction has subsided, the dose may be repeated. A slight fever for two days with temporary enlargement of neighboring glands is observed following the inoculation. The immunity does not continue long over thirty days and inoculations may be repeated.

The inoculations made by Haffkine in Bombay were quite successful. In the first experiment 8,142 persons were inoculated. Of these only 18 subsequently contracted the disease and 2 died. Among 4,926 persons inoculated a single time at Dharwar 45 were subsequently attacked and 15 died, while among 3,387 persons in whom a second inoculation was made only 2 were attacked. At the same period, the rate of mortality among those who held back from the inoculation rose to an unparalleled height, the deaths being 657 to 1,000 per week. The results elsewhere were equally good. The following table is excerpted from Surgeon-Captain Leumann's report. The conclusions to be drawn from it are self-evident.

Dates.	Census of Hubli.	Number of non-inoculated inhabitants.	Number of inoculated inhabitants.	Plague deaths among the non-inoculated.	Plague deaths among the inoculated.
Five weeks, from May 11th to June 14th, 1898	Fell from 50,000–47,427	44,573	2,854	47	1
Week ending (1898):					
June 21st	47,082	41,494	5,588	22	3
June 28th	47,485	39,042	8,443	29	1
July 5th	46,537	36,020	10,517	55	6
July 12th	46,518	33,255	13,263	34	6
July 19th	45,240	29,716	15,524	82	7
July 26th	43,809	24,112	19,697	100	15
August 2d	43,707	21,031	22,676	140	16
August 9th	42,768	15,584	27,184	272	19
August 16th	40,441	10,685	29,756	386	61
August 23d	39,400	6,367	33,033	371	41
August 30th	38,210	4,094	34,116	328	28
September 6th	38,382	2,731	35,469	227	34
September 13th	38,408	1,116	37,292	138	47
September 20th	39,142	937	38,205	106	55
September 27th	39,315	603	38,712	58	20

The government of India is now making a prophylactic from a vegetable culture medium which appears to be equally successful. The *Lancet's* Calcutta correspondent wrote (January 27th; 1900):

"In order to meet the religious scruples of a large section of the natives, experiments have for some time past been conducted in order to ascertain whether or not the plague prophylactic obtained by growing the bacilli of plague in a medium manufactured from wheat was as effective as that made in the ordinary manner from meat. For rabbits at least, the wheat-peptone vaccine is as effective as that prepared from meat peptone. Only one experiment has been made, but there is no reason to suppose that human beings will react differently. It is suggested that publicity be given to this experiment, so that those communities which have religious scruples against the use of vaccine prepared from goats' flesh may be made aware that they can now be protected by the use of the wheat-peptone prophylactic. The new material is ready for distribution."

In some experiments made to determine the efficacy of the different constituents of Haffkine's prophylactic, C. Balfour Stewart found that the sediment contains bactericidal properties, and that the filtrate alone is capable of conferring immunity or of modifying the attack.

Prevention of Epidemics.—The observations of sanitary authorities all over the world agree in one respect, and that is that the plague is a thoroughly preventable disease under conditions imposed by modern medical science, and that if these precautions can be freely carried out an epidemic will be impossible. As recommended by Roux, the attention of the sanitary authorities is devoted at the outset to the lower animals, the entire destruction of rats and mice being advised, and the cremation of their bodies. It is suggested that since the discharges from the nasal chambers of infected rats contain the plague bacilli in nearly pure culture, this may be one method of the extension of the disease. Since dogs and cats eat rats and mice, the propriety or necessity of quarantining or destroying these also must be considered. In the human subject, besides attention to ordinary hygiene, the use of Haffkine's prophylactic on a large scale is advised.

Lord Curzon, the Viceroy of India, recently before starting for a thorough inspection of the sanitary arrangements of the infected districts, took the precaution of having himself and entire party inoculated with the prophylactic serum. "A measure," he said, "which changes the death rate of from 70 to 80 per cent. into one of from 15 to 20, even in those who are attacked after submitting to it, to say nothing of the large proportion who are completely protected by it, is one which no sensible man can afford to neglect."

The value of the anti-plague inoculation has just been investigated by a government commission in India, which has carefully reviewed the entire subject and has reported that under the safeguards and conditions of accurate standardization and sterilization of the vaccine, together with the precaution of sterilizing the syringe in each case, the inoculations should be encouraged wherever possible and in particular among disinfecting staffs and the attendants of plague hospitals.* Lustig and Galeotti have used a nucleo-proteid as an immunizing substance, which they claim has marked advantages over Haffkine's prophylactic serum. Its efficacy has been proved by experiments upon animals. It is innocuous as regards man, being free from the toxic substances found in all cultural liquids used in their entirety. They make the specific charge against Haffkine's liquid that it easily becomes contaminated and there is no guaranty of the sterility of each separate bottle.†

Experience has shown that the doses laid down in the instructions for the use of the plague prophylactic by M. Haffkine require revision. This fact has been taken account of by the sanitary authorities in India, and an official order has been made in relation thereto. *The Lancet's* special correspondent says (February 3d, 1900, p. 345): "It has been found that children are less affected by inoculation than adults and can be given proportionately larger doses. Accordingly new rules have been promulgated and official instructions for the use of the plague prophylactic have been sent out. Considerable improvement has been effected in the matter of packing and fitting up the bottles. At one time this appears to have been carried out very insecurely and many bottles of the fluid were found to have undergone decomposition. The following dosage is now ordered:

	If the Dose Marked on the Bottle is—	
	2.5 c.c. then give	5.0 c.c. then give
Below 2 years	0.5 c.c.	1 c.c.
From 2- 5 years	1 "	2 "
" 6-11 "	1.5 "	3 "
" 12-15 "	2 "	4 "
" 16-50 "	2.5 "	5 "

It is thought that persons over fifty years of age should get 0.25 c.c. less for each decade above that age.

"The official instructions contain the following paragraph indicating the usual symptoms of plague inoculation: 'The symptoms commence, as a rule, three to five hours after inoculation and consist chiefly of swelling and pain at the seat of inoculation and of a rise of temperature. The pain is felt particularly on movement of the part. The fever is accompanied by general discomfort usual to this condition. No treatment of the symptoms is required beyond applying ice for the relief of headache, if any is felt, and enjoining some rest. General symptoms subside after twenty-four to thirty-six hours; the pain at the seat of inoculation lasts for three or four days, disappearing gradually; a painless induration remains for some time longer. It is desirable to produce a rise of temperature to at least 102° F. If the reaction is less marked the operation may be repeated three or four days later with the same or an increased dose, according to the result of the first inoculation. There is no harm in leaving a longer interval between the two inoculations. No changes in diet or occupation are necessary, beyond if possible insuring some rest. Bathing in the open air should be avoided for some days. A simple purgative may be given twenty-four hours after the inoculation.' "

Both the anti-pest serum of Yersin and Roux and the Haffkine prophylactic are now prepared in the hygienic laboratory of the United States Marine Hospital service at Washington, D. C.

In India investigations have also been made in the treatment of plague with the poison of the cobra, administered hypodermically, and diluted with glycerin. A dose of 1 mgm. was given, afterward increased to 2 mgm. Experiments upon monkeys were said to have given good results. Deane reports a mortality of 54 per cent. in 500 cases treated in this manner as compared with the average mortality of 70 to 80 per cent. (*Lancet*, July 8th, 1899, p. 121).

Turning now to the materia medica, the drugs to which we naturally look for assistance in treating such a typically infectious disease are the antiseptic and bactericidal agents. In fact J. M. Alkinson reported (in the *Lancet*, December 9th, 1899) a case of bubonic plague treated with large doses of carbolic acid with the recovery of the patient. Dr. Alkinson was induced to use carbolic acid in plague by the successful employment of large doses in the treatment of influenza and tetanus. The patient, a man of thirty-eight years, was admitted to the Government Civil Hospital, Hong-Kong, June 9th, 1899. Three days previously he had been exposed to contagion and the fever appeared two days later, or the evening before admission. After a preliminary calomel purge, gr. iij. (0.2 gm.) of carbolic acid were given every few hours, but this not being sufficient he was given a mixture of pure carbolic acid gr. xij. (0.75 gm.), syrup of ginger ʒ i. (or 4 c.c.), and chloroform water ℥ vi. (180 c.c.). Of this one ounce (30 c.c.) was given four times the same evening. On the following day the headache was much better, there was no evidence of toxic action, the urine was not blackened by the acid. A bubo was now found in the groin. The medicine was continued every two hours during the day. The patient's pulse and temperature had fallen on the 13th to 72 and 99.8° respectively. On the 15th the dose was reduced to gr. ij. (0.13 gm.) twice daily, and on the appearance of urinary symptoms was finally discontinued June 26th. During the acute stage, six ounces of brandy were given in twenty-four hours and the diet was liquid. The patient in three days, from June 10th to 12th, took over two hundred grains (13.33 gm.) with the result of lowering temperature, allaying vomiting, and relieving nervous symptoms.

There are other antiseptics less toxic than phenol to the human system, which can be given in larger doses, such as creosote, creosotal, guaiacol (and its benzoate or carbonate), betanaphtol, iodoform, resorcin, sodium hyposulphite, etc. The affected glands may be painted with pure guaiacol, or anointed with iodoform ointment or iodol dissolved in oil (gr. xx. to cod-liver oil, ℥ i.). If the glands are accessible, they may be extirpated or destroyed with the galvano-cautery.*

The imperative necessity of scrupulous antisepsis should be impressed upon the patient and all his attendants; the sputum, the œdema fluids, the urine, and all other discharges should be promptly mixed with chloride of lime solution, and, with all dressings, clothing, etc., destroyed by fire with the least possible handling or delay.

In order to guard a community against the introduction of an epidemic it was well said by Prof. Max von Pettenkofer that three things are essential to success. 1. A rigidly enforced quarantine to exclude the *fomites* or *materies morbi*. 2. By means of improved hygiene, personal cleanliness, diet, and other precautions, the individual should so far as possible be rendered immune from or less liable to the infection. 3. The locality should be purified from sewage and all filth that may form disease-breeding centres, pure water only should be used for drinking by the community and various similar precautions should be taken. Not only should the sick-room be disinfected, but the house should be similarly cleansed and the whole neighborhood made as clean as possible by the sanitary authorities. The free use of disinfectants to the discharges from the patient and to the surroundings is now regarded as an imperative duty and the directions given by the sanitary authorities are most explicit and comprehensive. The methods followed by the United States Marine Hospital service, and by the French and German governments are summarized in the report of General Wyman, already freely quoted from.

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* Brit. Med. Journ., February 24th, 1900, p. 461.

† Brit. Med. Journ., No. 2041, p. 311.

* "Encouraging results have followed surgical treatment in cases of bubonic plague. In a report to the Surgeon-General of the Marine Hospital service, Acting Assistant Surgeon W. Havelburg states that the clinical registry of the Paulo Candido Hospital, Rio Janeiro, Brazil, during the period from June 1st to August 31st, 1900, shows that there were 221 plague patients treated by extirpation of the infected glands, of whom 45 died, giving a death rate of about 20.8 per cent. And of 143 patients with solitary infected buboes, treated in the same manner, 23 died, showing a death rate of about 16 per cent. The diagnosis in all the above cases was confirmed by two bacteriological examinations, one before removal to the hospital, and the other after admission to the wards. Sero-therapeutic treatment was instituted in a number of other cases, but the effect of operating displayed such favorable results that injection of serum in the others was deemed unnecessary. The necropsy reports in the cases that died showed buboes that were inaccessible to operations, being scattered in the mesentery, or deeply situated in other tissues."—Journ. Am. Med. Assn., January 19th, 1901, p. 185.

A few words may be permitted to correct a popular error to which attention has been called by Dr. James Edmunds* of London. The impression prevails among a rather large proportion of the profession and the community that alcohol has a certain antidotal power against infection, and that, if when epidemic disease prevails, it will act as a prophylactic and confer a certain degree of immunity upon those who are under its influence. Alcoholic drinks, therefore, are often publicly recommended, when a community is threatened with an epidemic.

Whatever may be the result of such a course in other infectious diseases, experience does not warrant the view that it would be of any avail when plague is imminent. On the contrary, intemperance is now generally recognized as constituting or favoring a predisposition to the disease. Sydenham's observation is here very much to the point. "Certain it is," he says, "that the free use of wine, and other strong preservatives, taken at stated hours and in the way of regimen, has brought the disease upon many persons who in all probability would have remained safe and sound otherwise."

As the therapeutic and prophylactic problems relating to the plague are at the present day taken out of the province of the private medical practitioner, on account of the very important interests that are involved, and as the problems are now being studied seriously by the sanitary authorities of the various governments of the civilized world, they can have only an academic interest to the members of the profession in general and need not be dwelt upon further. The reader is referred to the publications of the national departments, and particularly to those of the United States Marine Hospital service, for detailed information on these topics.

John V. Shoemaker.

BUCHU.—*Short Buchu.* "The leaves of *Barosma betulina* (Thunberg) Bartling et Wendland, and *Barosma crenulata* (L.) Hooker (fam. *Rutaceæ*)" (U. S. P.). A third species, B. *serratifolia* Willd., "Long Buchu," was also once official, but was dropped because of its inferiority. The British Pharmacopœia rejects also the second-named species, which is greatly lacking in uniformity and which is now but little collected. There are about fifteen species of this genus, all natives of South Africa. The drug was in use by the Hottentots at the time of settlement by the whites. Its introduction to America was in the form of a notorious quack medicine, and was afterward adopted upon its merits by the profession.

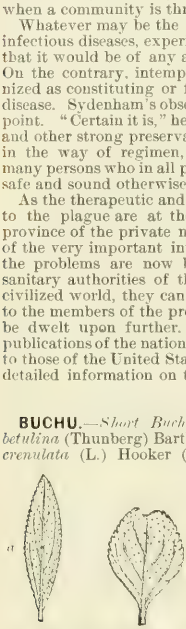

FIG. 1055.—Buchu Leaves. *a*, *B. crenulata*; *b*, *B. betulina*. (After Baillon.)

The leaves of *B. betulina*, the best variety, are mostly one-half to three-quarters of an inch long and two-thirds as broad or more, occasionally broader than long. They are abruptly contracted into a short, narrow basal portion, the broad upper portion being irregularly sub-rotund, the apex blunt, often recurved, the margin sharply and finely dentate. They are very thick, brittle when dry, smooth and somewhat shining, slightly papillose, and of a yellowish-green color. Against the light they are pellucid-glandular-dotted, with larger marginal glands. They have a strong mint-like odor and a warm, aromatic, and mucilaginous taste.

B. crenulata varies from oblong to oval or obovate, usually a little broader than our figure, and is often twice as long as the other, and less blunt. The margin is crenulate. It is also thick and greenish-yellow, and has similar pellucid glands.

B. serratifolia is markedly different from the others, being of a bright green color, thin, sub-three-nerved by the elongated basal pair of veins, narrowly oblong or lance-linear, sharply serrate, the teeth and sinuses curved. The leaf is about as long as the *B. crenulata*. There is a very large gland at the obtuse apex.

There is no adulterant of the official buchu, but when long buchu was official, the leaves of *Empleurum serrulatum* Ait. were used for that purpose. They are distinguished by the very acute apex and the straight, incised, salient, longer toothing.

COMPOSITION.—Official buchu contains 1 to 1.5 per cent. of volatile oil, long buchu half as much. There are also resin, gum, and a little of the bitter glucoside *barosmin*, believed to be the same as *hesperidin*. The oil contains a camphor-like body, often called buchu camphor (diosphenin $C_{10}H_{16}O_2$). There is but little of this in oil of long buchu, but that contains much of a body to which the peppermint-like odor is due.

ACTION AND USES.—Buchu acts locally as a mild stomachic. Absorbed, it possesses the ordinary diffusive stimulant properties of volatile oils, its special point of action being the kidneys, by which it is excreted. Its diuretic properties are mild, but it is distinctly sedative and astringent to the urinary organs, as well as slightly antiseptic. Henbane is often combined to increase the sedative effect. It is a mild expectorant. The fluid extract is official, and the dose is 1 to 2 c.c. (fl. ʒ ¼ to ½).

Henry H. Rusby.

BUCKBEAN.—*Bogbean. Menyanthes.* The herb of *Menyanthes trifoliata* L. (fam. *Gentianaceæ*). A widely distributed bog herb, with a creeping perennial rhizome, and thickish bright-green leaves, but which become very thin in drying. They arise from long, sheathing petioles. These leaflets are nearly entire, oblong or ovate, blunt, about 8 cm. long and half as wide (one and one-half by three inches). They have a disagreeable odor when fresh, which disappears upon drying; the taste is bitter and nauseous. The white or pinkish flowers are borne in an upright, spike-like raceme at the end of the rhizome, and are very beautiful.

Buckbean grows in cold swamps and moist places in Europe, Asia, and America, and has naturally been long known and used in medicine, but is now very little called for. Its bitter principle, *menyanthin*, was separated in 1860 by Kromayer as a white, amorphous, bitter powder, and shown to be a glucoside—sugar and a liquid oil, "menyanthol," being the result of its decomposition.

In moderate doses it is a simple bitter tonic, similar to, but less agreeable than, the other Gentianaceæ. In large doses it is cathartic, and sometimes emetic. Dose, as a tonic, 1 or 2 gm. (15 to 30 grains). *W. P. Bolles.*

BUCKEYE. ÆSCULUS.—*Horsechestnut* (fam. *Hippocastanaceæ*). A genus of about a dozen species, of America and Asia, growing mostly north of the Equator. The bark and seeds of *Æ. Hippocastanum* L., native of Asia, but largely cultivated for ornament in all temperate countries, have been much used in domestic practice in the treatment of malaria and rheumatism. Both contain considerable tannin, but the activity appears to reside in the bitter glucoside esculin ($C_{15}H_{16}O_9+1.5\ H_2O$) which is crystalline, white, soluble in water and alcohol, and antiperiodic in fifteen-grain doses.

The seeds of the red buckeye, *Æ. Pavia* L., of the southern United States, are reported to have caused fatal cases of poisoning in children, the symptoms being those of poisoning by saponin. It is even said that the former species has acted similarly. *H. H. Rusby.*

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* "Alcohol and the Plague." The Indian Lancet, December 1st, 1899, p. 472.

BUCKTHORN.—*Frangula.* "The bark of *Rhamnus Frangula* L. (fam. *Rhamnaceæ*), collected at least one year before being used" (U. S. P.). This is a very large shrub or small tree, growing throughout Europe and in adjacent Asia and Africa, and sparingly naturalized near New York City. The wood is very fine-grained, and its charcoal is largely utilized for powder-making, for which the bark must be first removed. The latter thus results as a by-product. It is largely employed in domestic veterinary practice, in the fresh or recently dried condition. It is then a sharply irritating cathartic or even emetic, but its griping properties are greatly mitigated by being kept. It occurs in strongly curved quills, which are commonly more or less flattened by pressure. The bark is very thin for the size of the quill (about 1 mm.$=\frac{1}{25}$ inch). The outer surface presents two forms, the one nearly black, the other dark-gray. Both are commonly marked by numerous transversely elongated white dots, and are somewhat warty-roughened, but never fissured or scaly. The inner surface, bright yellow when first collected, becomes successively dark yellow, brown, reddish, and nearly black with keeping, this being a fairly good way of recognizing its age. Its fracture is weak but not brittle, and is slightly fibrous. It has a slight characteristic odor and a bitter taste.

Composition.—With resin and a small amount of tannin, the important constituent of frangula is the yellow glucoside *frangulin*, or rhamnoxanthin ($C_{21}H_{20}O_{8}$) and its products *emodin* ($C_{15}H_{10}O_{5}$) and *isoemodin* ($C_{15}H_{8}O_{4}$). The development of all three of these substances proceeds as the dried bark ages, and coincidently the drug becomes a milder cathartic or laxative. Emodin and Isoemodin belong to the class of *Anthraquinones*, some one of which appears to give the properties to one large class of laxative drugs. Emodin, derived both from rhubarb and from frangula, is on the market. It is insoluble in water, little soluble in alcohol, but dissolves readily in alkaline solutions. It is not used medicinally in its own form.

Properties and Uses.—Frangula can be used as a cathartic in doses of 4 to 8 gm. (ʒ i.–ij.), but, like cascara sagrada, it acts much better as a laxative in doses of one-fourth or one-third these amounts. The fluid extract is official. Owing to its less mild and uniform action, frangula has almost entirely given way to cascara sagrada as a laxative.

The genus contains some seventy-five species, mostly in the north temperate zone, and gradually decreasing southward, in the mountains, a few in the south temperate zone. Many of them have a similar composition and action to that here described. *R. Cathartica* L. has especially been so used, both the bark and the fruits (buckthorn berries) having been used as cathartics from ancient times. The bark of at least one species, R. Wightii, of India, is a strong astringent.

Henry H. Rusby.

BUDDING.—One of the methods of asexual reproduction in the animal kingdom as well as in the vegetable world.

It differs from fission (*q. v.*) in that the offspring produced from the bud has never formed an integral part of the parent organism, but arises as an outgrowth of some part of the parent.

In its simplest form, as in the case of the fresh-water hydra (Fig. 1056), the process is as follows: Certain cells of the wall of the hydra grow and multiply, forming a hollow outgrowth on the side of the parent (*a*). As this enlarges and develops, tentacles appear at the outer end, and a mouth is formed (*a'*). Later, communication with the digestive cavity of the parent is cut off, and the young hydra feeds itself, and at a still later stage becomes separate from the parent.

In other cases the buds remain permanently attached, and thus are formed colonies, or stocks of greater or smaller size and complexity, often supported by a skeleton. Such are the coral stocks and many others. One example from the protozoa is shown in Fig. 1057, and one from the polyzoa in Fig. 1058.

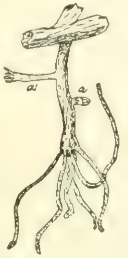

FIG. 1056. Hydra (enlarged). Showing buds, *a, a'*.

Buds may be formed at various places on the parent or colony. Very frequently they grow from the side of the parent—lateral budding, as in hydra and most corals; or on the top—apical budding (Fig. 1057). Sometimes buds are formed from stolons developed from the cœnosarc of the colony (Fig. 1058, *b*) or from the cœnosarc directly.

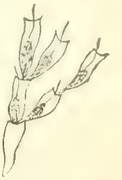

FIG. 1057. Dinobryon, an Infusorian (greatly enlarged). Showing apical budding.

A variety of apical budding, called axial, consists in the production of new segments, which may remain permanently united, as in most worms, or become detached, as in the tape-worm.

In some cases internal buds are produced, as in echinococcus (*q. v.*), and in the redia of the fluke-worms.

Closely united with this last method is the formation of germs, or unfertilized eggs, from organs corresponding to the ovary (parthenogenesis, *q. v.*), which develop into animals like the parent, as in the production of drone bees, plant lice, etc.

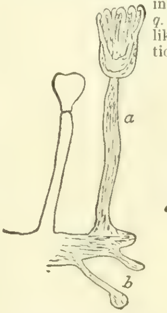

FIG. 1058.—Fredericella, a Polyzoan (much enlarged). Showing adult bud, *a*, and stolon, *b*.

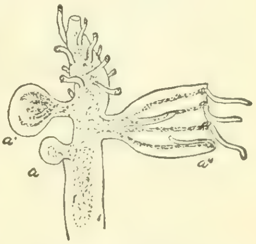

FIG. 1059.—Syncoryne, a hydroid. A nutritive zoöid with medusa (reproductive) buds (*a, a', a"*) in various stages of development.

A variety of this method, pædogenesis, consisting of the production of germs from animals still in the larval form, is exemplified in certain flies, as Cecidomyia, Miastor.

In some cases the buds of a colony are of different forms and functions. This is best seen in the hydroids, in which the feeding zoöids are of a different form from the reproductive zoöids (Fig. 1059, *a, a', a"*). This method of budding leads to colonial division of labor.

E. A. Birge.

BUENA VISTA SPRINGS.—Logan County, Kentucky.

POST-OFFICE.—Russellville. Springs Hotel. Accessible viâ Louisville and Nashville Railroad (Memphis branch) and Owensboro and Nashville branch to Russellville, thence by stage six miles to springs. The stage meets the train which leaves Russellville for the springs at 8 A.M.

This resort is located in a beautiful and picturesque region, interspersed with lofty hills, deep gorges, beautiful dells, and majestic native forests. The hotel has been rebuilt, and the guests will now find a large and commodious building, which will meet all the requirements of modern cultivated tastes. The springs, two in number, are situated in the lawn in front of the hotel, where they rise from their subterranean recesses, and flowing forty feet, empty into the creek. The following qualitative analysis of Spring No. 1 was made by Dr. L. P. Yandell, professor of chemistry and physiology in the University of Louisville:

Magnesium sulphate.
Calcium sulphate.
Calcium carbonate.
Magnesium carbonate.
Sulphureted hydrogen gas (abundant).
Carbonic-acid gas.

Dr. H. A. Utley's analysis of Spring No. 2:

Magnesium sulphate.
Magnesium carbonate.
Magnesium phosphate.
Potassium carbonate.
Potassium phosphate.
Sodium carbonate.
Sodium phosphate.
Iron phosphate,
Iron chloride, trace.
Calcium carbonate.
Free carbonic-acid gas.

The waters have been highly recommended by Kentucky physicians in liver disorders, malarial affections, rheumatism, skin diseases, anæmia, general debility, and other conditions. Various amusements, in the way of a tennis court, croquet grounds, billiard tables, swings, and walks over the hills and through the gorges are at the option of the visitor. *James K. Crook.*

BUFFALO LITHIA SPRINGS.—Mecklenburg County, Virginia.

Post-Office.—Buffalo Lithia Springs. Hotel.

Access.—Viâ Southern Railroad to Clarksville, thence eight miles by private conveyance to springs. Also viâ Atlantic and Danville (branch line), which delivers passengers immediately at the springs.

These celebrated springs occupy a central position in the section of country known as the Buffalo Hills, a broken, rolling district, having an average elevation of five hundred feet above the sea level. The hotel is open from June 15th to October 1st. The buildings are on the cottage plan and sufficient for the accommodation of two hundred and fifty guests. Among the attractions of the place is a well-appointed bathing establishment, affording ample facilities to visitors for mineral-water baths. The springs are three in number, and are designated respectively 1, 2, and 3.

They have been analyzed by Prof. William P. Joury, of the Maryland Institute, Baltimore. We append the analysis of Spring No. 2, which is richest in mineral ingredients:

One United States Gallon Contains:

Solids.	Grains.
Magnesium sulphate	0.88
Aluminum sulphate	9.07
Calcium sulphate	33.06
Potassium carbonate	29.30
Calcium bicarbonate	14.96
Lithium bicarbonate	2.25
Iron bicarbonate	.30
Baryta bicarbonate	1.75
Sodium chloride	4.92
Silica chloride	1.87
Phosphoric acid	Traces.
Iodine	"
Organic matter	Small amount.
Total	98.36
Gases.	**Cubic inches.**
Sulphureted hydrogen	8.30
Carbonic acid	59.20

This analysis shows what might be termed an alkaline-carbonated-aluminous-lithic-calcic mineral water. It possesses sufficient iron to give it ferruginous properties, but hardly enough to class it as a chalybeate. The water undoubtedly possesses valuable medicinal properties. The analysis would show it to be antacid, diuretic, and tonic. It has gained a wide reputation, especially in the treatment of the uric-acid diathesis, gout, rheumatism, renal calculus, stone in the bladder, and nervous and gastro-intestinal disorders. Spring No. 3 is a decided chalybeate, containing 3.77 grains of bicarbonate of iron to the standard gallon. It is also somewhat purgative in its action. On account of a heavy precipitate it is not offered for shipment, as are the waters of Nos. 1 and 2. These latter have an extensive sale throughout the country. *James K. Crook.*

BUGLE.—*Ajuga reptans* L. (fam. *Labiatæ*). A hairy European annual, with a rosette of spatulate, finely serrate leaves near the ground, and an upright, slightly leafy stem. The flowers are small and blue, labiate, but with very small upper and larger lower lips. Stamens four, didynamous, with divergent anthers. The leaves are official in France; they have a slightly bitter and astringent taste, but little odor, and no valuable medical properties. Dose indefinite.

The genus contains about thirty species, a number of which have had their day as medicines. *Ajuga Chamæpitys* Linn. (ground pine) grows also in this country. It is more aromatic than bugle, and reputed to be "stimulant, diuretic, etc." *W. P. Bolles.*

BULPISS.—An affection of the skin occurring in the northeastern part of Nicaragua and called by the natives "bulpiss." The word is derived from "buluy," in the language of the Mosquito Indians meaning *spotted*, and "piss" meaning *gray*—terms that appropriately describe the indivdual affected. The disease was first described in notes sent by Dr. Otto Lerch from Central America to Dr. Isadore Dyer of New Orleans asking for a diagnosis of this unusual affection. The notes were published in the New Orleans *Medical Journal*, 1894–95. Bulpiss appears to be an endemic disease affecting every tribe inhabiting this part of Central America, attacking any individual irrespective of age, sex, or general condition. Cases in very early infancy are, however, rare. It causes no disturbance of the general functions of the body. There appear to be several varieties, two distinct: (1) Black bulpiss; (2) white bulpiss.

The disease commonly starts on the hands and feet, spreading gradually and becoming more marked on the knees, abdomen, neck, and face.

The lesion is a minute reddish papule appearing in crops; they break up gradually, disappear, and leave discolored spots, the pigment of which finally disappearing too, leaves behind a dirty, whitish, dry, scaly patch with a partly discolored and slightly elevated broad margin—the white bulpiss. These patches are round or oval in shape with irregular border. In the black bulpiss the lesions are of a greasy black color, the affected skin having the appearance of being painted, the patches gradually drying and shrivelling. The only and common subjective symptom in both forms is that of itching, which occurs as the disease comes out and after bathing and at night. The disease is not hereditary. It is contagious and the duration seems indefinite. It is more than probable that it is parasitic in nature, as might be inferred from the remedy commonly employed—the red oxide of mercury ointment. *Charles Townshend Dade.*

BURDETT MINERAL WELLS.—Caldwell County, Texas.

Post-Office.—Luling. Hotel.

Access.—Viâ San Antonio and Arkansas Pass Railroad to Burdett Switch, where carriages meet trains for the springs during the summer season. The location is seven miles north of Luling, on the Galveston, Harrisburg and San Antonio Railroad.

Only one well is in use. The water has been employed for medicinal purposes for thirty years. According to a qualitative analysis made in 1877 by H. W. Johnson, of Boston, Mass., it contains the following acids and bases:

Acids.	Bases.
Sulphuric acid.	Calcium.
Carbonic acid.	Magnesium.
Silicic acid.	Aluminum.
Hydrochloric acid.	Manganese.
Boric acid.	Strontium.
Phosphoric acid.	Iron.
	Potassium.
	Sodium.

We cannot positively classify this water from the above ingredients, but it appears to belong to the class of alkaline-chalybeate waters. *J. K. C.*

BURDOCK. LAPPA.—"The root of *Arctium Lappa* L. and of some other species of *Arctium* (fam. *Compositæ*)," U. S. P. Burdock is a native of Europe, but is common everywhere as a garden weed. It is a rank-growing, bitter, disagreeable plant, from 1 to 2 metres (three to six feet) in height, with a stout, branching stem, and great, coarse, heart-shaped leaves. The flower heads are clustered along the stem and branches; they are rather small, and look like miniature thistles. The involucre is ovoid and green; its scales are numerous, imbricated in several rows, with spreading, sharp, stiff, inwardly hooked tips. Flowers are tubular and perfect, rose-purple.

The root is the official portion, and should be gathered at the end of the first season, or the beginning of the second; it is biennial, fleshy, and usually simple. When dried, it is in gray-brown, wrinkled pieces, as large as the thumb, and 20 or 30 cm. long (eight to twelve inches), often split, to facilitate drying. The hairy bases of leaf stalks may remain attached to its upper end, or there may be a cottony or woolly bud at the crown. Internally it is light brown, with a rather thick bark, a distinctly radiated woody zone, and a white, often broken or missing pith. Odor slight; taste mucilaginous and slowly bitter.

Burdock contains *inulin*, *mucilage*, nine per cent. of fat, a slight amount of amaroid, *lappin*, and a little tannin. Its inulin, which is in large amount, up to forty-five per cent., and its fat well adapt it to use as a food, and it is said that many cultivated varieties of it exist in Japan for this use. It is an old medicine, whose reputation depends upon pure empiricism. As an alterative and an antisyphilitic it is still occasionally used, but is more called for as an ingredient in proprietary medicines than in serious medication. Dose from 2 to 4 gm.

A fluid extract is official. *Burdock fruit*, a small, black, curved, rough, seed-like akene, is much less used, but much more efficient. It contains a considerable amount of bitter glucoside and pungent resin. Its action appears worthy of investigation. The dose is 1 to 2 gm. (gr. xv. to xxx.). *W. P. Bolles.*

BURLINGTON.—Vermont, a city of 14,590 (census of 1890) inhabitants, is situated in the northern part of Vermont, upon Lake Champlain, at an elevation of 377 feet above sea level. On the east are the Green Mountains, on the west is the Lake, and beyond this are the Adirondack Mountains. The climate is salubrious, not excessively cold in winter, nor excessively hot in summer. The mean relative humidity for the year is 68.2 per cent. There are frequent high winds, but no fogs. The proportion of bright and sunny days is said to be large. The mortality is 16.38 per thousand. The soil is generally dry and sandy.

The outdoor attractions are, in summer, yachting, rowing, canoeing, swimming, riding, driving, bicycling; in winter, sleighing, coasting, tobogganing, snow-shoeing, skating, and ice-boating. The University of Vermont is situated here. The accommodations are good, there being first-class boarding-houses and two fair hotels.

The annexed table shows the various climatic conditions of this place.

CLIMATE OF BURLINGTON, VT. LATITUDE, 44° 29′; LONGITUDE, 73° 15′. PERIOD OF OBSERVATION, TEN YEARS.

	January.	July.	Year.
Temperature (Fahrenheit scale)—			
Average or normal	18.9°	70.9°	44.8°
Average daily range	18.5	19.0	
Average of warmest	27.4	80.1	
Average of coldest	8.6	61.1	
Maximum or highest	51.0	96.0	
Minimum or lowest	−24.8	47.0	
Humidity—			
Average mean relative	72.3%	66.1%	68.2%
Precipitation			
Average in inches	1.90	3.76	28.48
Wind—			
Prevailing direction	S.	S.	S.
Average hourly velocity in miles	8.3	5.7	7.2
Weather—			
Average number of clear days	3.2	7.1	63.3
Average number of fair days	12.7	16.2	153.4
Average number of fair and clear days	15.9	23.3	216.7

NOTE.—If the above table is not understood, the reader is referred to an explanation of the terms under the article *Baltimore*.

Edward O. Otis.

BURNET.—*Radix Pimpinellæ.* This name is applied to the roots of *Pimpinella saxifraga* L. and *Pimpinella magna* L. (fam. *Umbelliferæ*), both of which are wild as well as cultivated in Europe. They are small tapering roots similar to and of the size of small carrots. They contain the ordinary constituents of the roots of this family, volatile oil, resin, gum, and a bitter principle, and are used like the related aromatics, the dose being 0.5 to 2.0 gm. (gr. viij. to xxx.). *H. H. Rusby.*

BURNS AND SCALDS.—Burns are injuries produced by fire or dry heat and scalds are the results of the application of hot fluids or moist heat. Clinically the results of these forms of injury are very much the same. The degree or severity of the burn varies according to the degree and duration of the heat and the capability of the solid or liquid for retaining caloric. Burns or scalds may be caused by the rays of the sun or by contact with fire, boiling water, oils, heated or molten solids, caustic alkalies, or concentrated acids; the amount of injury caused varying from a simple erythematous blush to the charring of a limb or part. The effect also varies according to the mode of application of the heat. To quote Wilson: "In degree, heat may be feeble but prolonged, or it may be strong and instantaneous, strong and continued for a brief period, or strong and continued for a long period."

The flame of burning ether or alcohol, if momentarily brought into contact with the living skin, causes a superficial burn, while the contact of burning sealing wax or boiling oil, the capacity of which to retain caloric is greater than that of water, because of its greater density, gives rise to much more serious injury. Molten metal when it simply strikes the skin causes vesication; but if it gains access to and surrounds a limb, complete charring and destruction of tissue occur.

A scald, even if severe, may leave the hairs uninjured, and from this circumstance it may often be diagnosticated from a burn; but when the liquid is hot and dense the hairs are often destroyed as in burns.

Concentrated acids and caustic alkalies, either in solid or in liquid form, act with great power on the soft tissues, and so cause injuries of the most serious character. Burns from this cause may be distinguished by the absence of vesication and other symptoms which are present when fire has been the cause.

Phosphorus acts energetically, causing deep and rapid burns and inflammation of surrounding tissues, and fatal results have attended its improper handling. Surface burns from lightning stroke present about the same appearances as burns from other sources. The skin is reddened and blistered, and the hair is singed or entirely destroyed.

Burns from nitric acid produce yellowish stains or patches, while sulphuric acid and caustics generally cause reddish or red-brown discoloration.

Sunburns are generally so slight as to require only a brief notice, yet occasionally a person having a tender skin may suffer severely from only a brief exposure to the sun. This burn is characterized by diffuse redness of the exposed part, with more or less smarting pain. The face, neck, forearms, and hands are usually affected.

Grave symptoms sometimes arise when a large surface (two-thirds) is implicated, and a case has been reported in which death occurred from violent dermatitis, with gangrene, following sunburn.

Burns are usually classified as of the first, second, or third grade. Dupuytren's division into six degrees is too complicated, and, though it was for a long time in vogue, it has been generally discarded by modern writers. The following classification is that of Thomas George Morton, and is the one generally accepted:

BURNS OF THE FIRST DEGREE.—Characterized by erythema, irritation, and inflammation of the skin without vesicles.

BURNS OF THE SECOND DEGREE.—Vesication, inflammation of the skin, and formation of vesicles and bullæ.

BURNS OF THE THIRD DEGREE.—Eschars; gangrene, superficial or deep, involving the skin or the subcutaneous tissues; carbonization of a part or of the entire body.

PROGNOSIS.—The prognosis depends upon the depth of the injury and its extent, upon the susceptibility of the skin to the action of heat, and upon the general characteristics and physical condition of the patient. Burns of the first and second degrees generally result favorably, the patient recovering rapidly; in those of the highest degree, however, when the surface involved is very extensive, the prognosis is more grave; and even burns of the first degree may prove fatal when a great extent of surface is involved. It is generally accepted that, if one-half or even one-third of the surface has been burned or scalded, death, from some physiological cause as yet not clearly explained, will be inevitable; and this usually happens during the first twenty-four or forty-eight hours. I think, however, that much depends upon the patient's previous physical condition and mental equilibrium. In two cases which came under observation during my service in Bellevue Hospital, the burns involved more than half of the entire surface of the body, in varying degree at different points; but these patients both recovered. One of them was a strong and healthy engineer, the other a robust Italian laborer. On the other hand, even slight burns, in aged and enfeebled subjects, are sometimes a cause of death through shock. In all these cases, therefore, a guarded prognosis should be given. In burns of the third degree, which result from the application of intense heat, the prognosis will depend not merely upon the depth of the burn, but also upon the part of the body involved, and upon the age, sex, and temperament of the patient.

SYMPTOMS.—*In burns of the first degree* there is more or less redness of the skin, which disappears on pressure, and which is accompanied by swelling and pain. This continues for a longer or shorter period, and then the epidermis is exfoliated and the natural conditions are restored. Recovery generally ensues in a few days and no permanent injury results. The constitutional symptoms are usually slight. Sometimes there is, however, an irritative fever, and if a great extent of surface has been injured, and if the patient is very susceptible, shock may be quite marked and even death may result.

In burns of the second degree the pain, redness, and swelling are more marked than in the first degree, and, the hyperæmia being greater, there is a tendency to exudation, and vesicles are formed. These, when large in size, are called bullæ. They either come on at once or form in a few hours. The serum is usually transparent, though sometimes it may be discolored by blood. Usually, along with the formation of the vesicles, the skin proper receives no damage, but sometimes suppuration and ulceration may take place. The constitutional symptoms vary according to the extent and severity of the injury. Shock is almost always present, and death results in some cases simply from this cause. Sometimes there is found a congestion of all the viscera, and death may result from cerebral effusion with delirium. With the rise in temperature, albumin is commonly found in the urine, and during the period of reaction ulceration of some portion of the mucous membrane of the bowel frequently occurs.

Burns of the Third Degree.—In this group are classed all cases of gangrene resulting from burns affecting the skin or subcutaneous tissue. Now, according to the intensity and duration of the heat, the skin alone, or the muscles, nerves, blood-vessels, and bones also, may be destroyed even to carbonization. This latter is, fortunately, a rare occurrence, but it sometimes happens that portions of limbs are entirely burned off while the individual is in a drunken stupor or is suffering from epileptic coma. The constitutional symptoms are, as may be supposed, severe. If reaction occur at all, the symptoms become at once quite grave, in proportion to the extent of the injury. In some cases death soon takes place from coma, due to cerebral congestion. The lungs, kidneys, and other organs are intensely congested, and this period of inflammation, so called, extends from the period of reaction to the beginning of exhaustion, during which time the dead tissues are being thrown off by suppuration. This exhaustion is sometimes increased by hemorrhages from the necrotic tissues. In all cases of burns of the third degree renal congestion is constant and gives rise to albuminuria.

THE COMPLICATIONS of burns may involve either the brain, or the respiratory tract, or the intestines. Cerebral irritation often appears quite early, and inflammation may follow and be accompanied by violent delirium. Convulsions and coma may occur in a fatal case.

Laryngitis, bronchitis, or pneumonia may occur from burns or scalds, the first frequently following the inhalation of hot steam. Œdema may be excessive, requiring tracheotomy in order to avert impending death from dyspnœa. Bronchitis and pneumonia are frequently observed to follow burns of the chest and neck.

Intestinal ulceration is one of the peculiar results of severe burns, and follows the intense congestion of the digestive tract that sometimes takes place. The intestinal lesions are present in varying degrees, from the simplest gastric irritation and diarrhœa to severe inflammation of the stomach and intestines, going on to duodenal ulcer, perforation, and death.

TREATMENT.—This varies in accordance with the severity of the injury. The indications are: First, to relieve the pain and overcome the shock; secondly, to guard against congestion and inflammation of the internal organs; and thirdly, to counteract the exhaustion incident to sloughing and suppuration.

Local Treatment.—In burns of the first degree there are usually no marked constitutional symptoms, but the local ones may be quite severe. These may be relieved by local applications of olive oil, vaseline, oxide of zinc, or other ointments of a soothing nature. Powdered bicarbonate of sodium is a most excellent application, and in simple burns it often affords great relief when freely dusted over the affected surface. Other alkaline applications may be used, among which a mixture of linseed oil and lime water, called "carron oil," may be mentioned as having long been popular. Flour, starch, white lead, paint, or any substance that excludes the air and makes a coating for the nerve filaments that have been irritated or uncovered will relieve the pain. Molasses has been used when nothing better could be found at hand in a case of emergency. The addition of carbolic acid to any of the ointments, or vaseline, or oil, is of much advantage, as it relieves pain and thoroughly disinfects any discharge that may occur. It produces a certain amount of surface anæsthesia, and, as carbolic acid is absorbed but feebly from any mixture with an oil, the danger of poisoning is not great. The urine should, however, be watched for any trace of the acid, as cases of such poisoning have occurred. An ointment made of boric acid and vaseline—*e.g.*, in equal parts—is of great service, as it allays pain and is perfectly safe. These remedies may be spread upon lint or old muslin and laid upon the burned surface, the parts being then enveloped in layers of cotton batting and all held in place by a roller bandage.

In burns of the second degree, in which we have vesication and inflammation of the skin, with the formation of bullæ, it is absolutely necessary that the injury should be regarded as a wound and treated accordingly; *i.e.*, the burn should be rendered aseptic and kept so, if possible. It is well to bear in mind that only one part of a burned patient should be exposed at a time, in order to avoid surface chilling. Vesicles and bullæ should not be broken, but should be punctured at their lowest point and their contents allowed to drain off, and care should be taken that the cuticle should not be rubbed off, as it affords an excellent protection for the excoriated surface. The burned surface should be thoroughly cleaned; any cinders or any portions of clothing or charred material should be carefully removed, and the part should be rendered as aseptic as possible by washing and by the application of solutions such as mercuric chloride (1 to 10,000 or 20,000), aluminum acetate, etc. After these have been washed off with warm, decinormal salt solution, the burned surface may be covered with sterilized rubber tissue, which in turn is to be covered by a thick layer of sterilized gauze that is held in place by a roller bandage. When the inflammation of the skin is intense, a wet dressing of aluminum acetate or of ichthyol solution (three to five per cent.) should be applied and kept continually moist. Such an application will tend to relieve the pain and to render the burned surface aseptic. The rubber-tissue dressing, with its thick covering of sterilized material, acts as a substitute for the destroyed integument; it excludes the air and makes an excellent and painless covering. If now the wound has really escaped being infected, it will rapidly become covered by a renewed epithelial surface.

The dressings need not be changed oftener than every second or third day, unless the amount of discharge is very great or the odor quite marked.

It is quite proper to mention here the method of treatment of burns of the body, as well as of one extremity, by immersion. The clothing of the patient being removed or cut away, the limb or limbs or the entire body may be placed in a bath of decinormal salt solution, which should be maintained at a temperature of about 100° F. and not allowed to drop below 98.5° F. In cases of extensive burns, in which both legs and portions of the body have been involved, the placing of the patient in a bath of this character produces great relief, particularly as regards the pain and the amount of shock. The solution, which should completely cover the burned part, gives immediate ease, as it excludes the air; and, furthermore, if the temperature of the bath be raised sufficiently, there will be provided a most efficient remedy for the condition of shock. This form of bath not only cleans the injured portion of the body thoroughly, but at the same time renders it aseptic and maintains it in this state for a certain length of time. From time to time, as the solution becomes fouled, it will be necessary to renew it. The patient should not be removed from the bath until all sloughs have been separated and the denuded surface is ready for grafting. Propped on rubber air pillows, the patient may sleep or rest in the bath without danger. Provision must be made, however, for maintaining the temperature of the bath, and for keeping up its proper saline proportions.

In burns of the third degree, I would mention the fact that sometimes it will be found advisable to resort to an early amputation. The adoption of this course is indicated when the area burned is so extensive that the subsequent suppuration might prove too great a drain upon the patient's strength, or when this area occupies such a position that even if perfect healing should take place the remaining cicatrix would be constantly exposed to ulceration through the effects of abrasion or would seriously interfere with the use of the limb.

When the sloughs have separated, the ulcerated surfaces beneath are soon covered by florid granulations, which may require astringent applications or strapping with adhesive plaster. The treatment now becomes that of a simple ulcer, and may be guided by the same rules. Much good may be accomplished and deformity be avoided by keeping the various parts carefully separated, and by maintaining them in an appropriate position either by fixation on splints or by some proper mechanical appliance.

In the ulcerative stage skin-grafting is at times of great service, and large and indolent ulcers may be made to heal quite readily by this means (see article on *Skin-grafting*). Even transplantation of skin, as recommended by Wolf, may be employed with advantage in certain cases. If the patient, for example, has a large denuded surface, grafting becomes imperative; and the method of Thiersch is the best one to employ under these circumstances, provided the patient can be confined to bed in proper quarters. If, however, this is impossible, the epidermization of the denuded surface may be materially hastened by employing the method of engrafting portions of corns or callous portions of the skin upon the exposed granulating surface. As the details of this procedure are given in a later volume it will not be necessary for me to mention them in this place.

Treatment of Burns from Corrosive Acids, Caustic Alkalies, etc.—The corrosive or mineral acids which most often cause burns are sulphuric, nitric, and muriatic. In burns from these acids the application of water is to be avoided, as it causes, when mixed with the acid, a great and sudden rise of temperature. The proper treatment is to apply whiting or levigated chalk, which causes brisk effervescence, and at once neutralizes the acid; after this the part may be washed off with water. If this is done promptly, no more serious injury will result than a faint erythematous redness, accompanied by a slight sensation of smarting. Should by chance any of these substances be splashed into the eye, the organ should be well bathed in lime water, and subsequent inflammation should be treated in the usual manner.

The caustic alkalies are soda, potassa, ammonia, and quicklime. These act by suddenly abstracting moisture from the tissues. A fresh burn of this nature should be treated with vinegar, or with any other mild acid, which neutralizes the alkali, and forms with it an unirritating salt. A burn of the eye should be treated in the same way, care being taken to dilute the acid to a proper degree.

The treatment of shock from burns or scalds should be the same as when this condition arises under other circumstances. (See article on *Shock*.)

When reaction has commenced, a generally supporting plan of treatment is in order. Thirst, which is usually intense, should be allayed by small lumps of ice placed in the mouth, or by occasional sips of carbonated water. Constipation is quite common during the first two or three days following a burn, and a laxative enema affords the best means of relief. The gastric and intestinal disturbance often calls for treatment. The diarrhœa during exhaustion due to the profuse suppuration is best treated by opium combined with astringents, and by pepsin and bismuth. The diet should be simple but nourishing, and absolute rest is to be enforced.

John McG. Woodbury.

BURNS AND SCALDS, THE MEDICO-LEGAL RELATION OF.—The application of a moderate degree of heat to the surface of the body acts as a stimulant to the activity of the cutaneous transpiratory system, through its effect upon the capillary circulation. If the heat be raised beyond this degree, and to one incompatible with the integrity of the tissues, there results what has been denominated a burn or scald. Such difference of designation is based upon no special difference of character, but upon the nature of the causative agent.

For all practical purposes it is not essential to make a distinction between burns and scalds, yet it is sometimes important to decide upon the cause of the lesion observed.

Definition.—A *burn* is an injury resulting from the application to the body of a highly heated substance, flame or radiant heat. A *scald* is an injury produced by the application of a liquid, at or near the boiling-point.

Classification.—Burns are most simply classified according to the severity of their injurious effects. They may accordingly be considered as:

I. Burns involving the skin and subcutaneous cellular tissue only.

II. Those which extend their injurious effects to the muscles, nerves, and blood-vessels.

III. Burns involving in their effects the internal organs and bones.

IV. Those in which the preceding classes are variously combined.

Class I. In this are included those burns in which a short contact with a heated body, or with water at or near the boiling-point, causes redness or scorching of the skin and considerable pain, leaving no permanent mark.

Class II. In the least severe cases the cuticle is destroyed in its entire thickness, and the injured parts are covered with yellowish-gray or brownish eschars. The skin surrounding the burned surface is reddened and, immediately or after a few hours, blisters are formed. Such cases heal without deformity and leave a shining cicatrix. In the severer cases the subcutaneous cellular tissue, the muscles, and the nerves are destroyed. Blackish eschars form which are without sensation and, ultimately, are thrown off by the process of suppuration, leaving a granulating surface. The surrounding tissues are reddened and usually a greater or less amount of vesication exists. In the healing process, the resulting cicatrices of the skin adjacent are prone to contract and produce deformity which in some cases, especially when affecting the head or extremities, demands extensive surgical interference.

Class III. So severe are the effects of burns of this class that the result is rapidly fatal. They are usually caused by an exposure to flame or to intense heat, more or less prolonged, and not only involve the lesions already noted, but also a charring or carbonizing of the parts exposed.

Causes Indicated by Appearances.—Burns of any intensity may be produced by a heated body, according to the degree of the elevation of its temperature and the period during which contact is maintained. The shape and size of the object are often indicated by the burn. These appearances may vary from a simple reddening of the skin to a complete charrring of the parts. At the temperature of the boiling-point, 100° C., metals are capable of producing redness, vesication, and other effects. Partly fused solids cause burns of greater severity than substances which can be readily removed from contact with the body, since, by their adhesion to the skin, they are prone to tear away portions of the derma in their removal. Such burns resemble, in their appearance and effects, those produced by solid bodies. They are less regular in outline, however, and are usually more severe on account of the high temperature of the agent causing them. Burns of this character are characterized as *scalds.*

Boiling water produces scalds which may be so slight as to produce moderate redness only, or be so extensive as to develop quite characteristic effects. Such special effects are an ashy hue of the skin, with a sodden appearance, and the formation of blisters. While these features are usually characteristic of scalds by hot water or steam, they are sometimes with difficulty distinguished from burns by other agencies. Blackening of the skin never occurs in burns caused by boiling water. Gangrene sometimes develops in cases which are not necessarily fatal. Scalding with hot water, though sometimes demanding legal investigation, is usually accidental. Severe and fatal burns of the mouth, fauces, and larynx are occasionally seen, from the inhalation of steam or from swallowing boiling water. These usually occur in children who attempt to drink fluids from teapots or teakettles.

Burning oil produces burns similar to those by molten metals.

Flame causes a scorching of the surface which is characteristic. In burns from this source the hairs upon the injured part are scorched and often upon those parts adjacent. This serves to distinguish burns from this cause from scalds from boiling water or steam, or by boiling oil, or by a hot body.

Petroleum and its derivatives produce burns similar to those caused by flame, but in addition to the scorching the parts burned are blackened and more deeply injured than by flame alone, since the clothing usually holds the burning agent in contact with the body. The odor peculiar to the substance is ordinarily noticeable.

Acids and corrosive agents cause severe burns. Besides injuries accidentally occurring, wilful injuries by the use of such means sometimes require investigation. While no fatal case from this cause is recorded, malicious attacks by throwing "vitriol" (strong sulphuric acid), have occasionally occurred, resulting in loss of sight and severe disfigurement.

The appearances of a burn by a mineral acid are easily distinguishable from those caused by heat. The eschar of a burn by an acid is soft, and sloughs readily, while that caused by heat is hard and tough. Around the site of the burn no redness, blackening, scorching of the hairs, or blisters occur, and the color of the burn is uniform. The stain upon the surrounding parts often affords means of distinguishing the agent which has caused the injury. Sulphuric acid produces a dark brown stain, nitric acid a yellow, and chlorohydric acid a brownish-yellow stain. The clothing also furnishes similar evidence by discolorations, and by a chemical analysis of the fabric. A post-mortem burn by an acid is not distinguishable from an ante-mortem burn, unless a vital reaction has occurred.

Effects of Burns.—These are *local* and *constitutional.*

1. *Local Effects.* Redness, blisters, destruction of the cuticle, scorching of the hair, and roasting of portions of the body occur, according to the extent and severity of the burn. In some severe cases, all these appearances are to be seen on the same body. Within a short time after the occurrence of a burn a special *line of redness* appears between the part burned and the uninjured skin. This *red line* is caused by highly congested vessels and, in some cases, becomes a medico-legal sign of much importance. *Blisters* may be single or multiple; some of these may be unbroken, others may be ruptured and their serum may have flowed out upon the surrounding parts. In some cases the skin, made dry and brittle by the heat, develops *cracks* and *fissures* by the movements of the patient. These most frequently occur in the vicinity of the joints. Occasionally these fissures resemble incised wounds, and it becomes necessary accurately to establish their character. Their depth depends upon the depth of the burn. In the more superficial cases the skin only is fissured, leaving the subcutaneous fat exposed, which may partially melt and flow out upon the sides of the fissure. In such cases the blood-vessels may usually be seen stretching across the crack, not having been destroyed in consequence of their elasticity. They should always be carefully sought. In severer burns the vessels are involved and break with the opening of the fissure.[*]

Should it become necessary further to differentiate between such a fissure and a wound made by a sharp instrument, the condition of the edges of the fissure, whether clean-cut or ragged, and the presence or absence of uncut vessels and evidences of hemorrhage upon the surrounding parts, will complete the differential diagnosis. It must be remembered, however, that incised wounds and wounds from the action of fire may be found upon the same subject. Each wound noted, therefore, must be specially examined as to all its characteristics of position, depth, shape, and other features.

2. *Constitutional Effects.* The constitutional effects of a severe burn are manifest in the condition of "shock," which is induced by all sudden and severe injuries. The predominating symptoms are pallor, with coldness of the surface of the body, a feeble pulse with chills, and a tendency to collapse. In cases which are quickly fatal, obstructed respiration supervenes, and death from coma follows. Occasionally, convulsions precede death; while

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[*] Casper, "Forensic Medicine," i., 301, 314.

in cases not immediately fatal, a reaction, more or less marked, occurs.

Causes of Death.—Death may follow from cerebral congestion or effusion before any reaction is apparent. Pulmonary congestion and œdema, with pleural effusions, occur in other cases, death supervening before the appearance of any evidences of reaction. Such fatal result usually takes place within the first two days; while, in some cases, the issue is immediately fatal from the prostrating effects of the intense pain. During the two weeks succeeding the infliction of the burn, the period of inflammatory reaction occurs, in which the case may terminate fatally, from the development of inflammatory conditions of the thoracic and abdominal viscera, with or without ulcerative processes in some organ.

Death may be due to one or more of several conditions, arising from important modifications of visceral organs. Such modifications result from the intimate relation existing between the sympathetic nervous system and the spinal cord, and that of the nervous supply of the surface of the body and the internal organs. These changed conditions may induce death *immediately*, or *after an interval.* The conditions immediately fatal are those which cause death by *asphyxia*, through deprivation of air, or by *suffocation* from inhalation of carbon monoxide and carbon dioxide, produced by combustion.

Death may result from *syncope* or *collapse*, induced by nervous shock and pain. A fatal issue, after a short interval, may be caused by *cerebral congestion* and *effusion;* by *bronchitis*, or *pneumonia* with congestion or œdema of the lungs; by inflammation of the intestines, causing *peritonitis* and *ulceration;* by *gangrene* or *septicæmia* or by *exhaustion* resulting from prolonged pain and suffering.

From a medico-legal standpoint it may be necessary to determine the extent of a burn which must, necessarily, prove fatal. While burns and scalds are not legally classed as wounds, they are included among injuries dangerous to life. It must be remembered that upon their *extent*, rather than upon their depth, is the danger dependent. Destruction of a considerable portion of the transpiratory tract, or the suspension of its function by an extensive superficial burn, is far more fatal in its tendency than a deep burn of a limited portion of the body. The character of the burn, whether single and continuous or multiple and in small patches on various parts of the body, is an important consideration. The part affected has a very direct relation to its fatality. Burns of the extremities are less fatal than those of the trunk; while burns of the genitals and the lower portion of the abdomen are especially so.*

The physical condition of the person has a very pronounced influence. Burns in females and children of highly nervous organization, render an unfavorable prognosis necessary. It may be stated that a burn involving two-thirds of the surface of the body is necessarily fatal, but a small area of injury of even one-fourth of the surface has proved fatal. Such a general statement is quite as scientific as an attempt to define an exact area of square inches.

Period at which Death Occurs.—As previously stated, death may occur almost immediately from direct effects, or after a period of five or more weeks. Death, in the majority of cases, occurs during the first five or six days.

How long a person may have survived the infliction of the burn is sometimes a most important question. The probable time which has elapsed is indicated by the presence or absence of suppuration. The development of this condition, if existing, would indicate a period of two days or more, since inflammation and suppuration would not begin, ordinarily, before the third day. Intestinal inflammation or ulcerations, which usually require several days for their development, would also afford suggestions as to the time elapsed.

Post-mortem Appearances.—*Externally*, the examination of a burned body calls for a special note as to the sex, probable age, and every condition bearing upon the identity of the individual. The burned parts should be carefully examined as to the condition and extent of the injury. The presence or absence of redness, blisters, charring, and fissures should be particularly noted and the area of the burned surface carefully computed; as also the relation of the burned portions to uninjured surfaces, and whether the line of separation be sharply marked or gradually fade into the surrounding skin. If blisters are present they should be examined in order to note whether they be full or empty, and as to the character of their contents, whether consisting of a clear or a turbid and colored serum.

Internally, the examination sometimes reveals no lesions, such persons usually dying from shock or from the intensity of the pain. Ordinarily the mucous membrane of the trachea and bronchial tubes is congested and, when asphyxia or suffocation has caused death, dark, sooty or smoky mucus is found in the respiratory tracts. In many cases the serous membranes of the abdomen, thorax, and brain are found to be reddened. The sudden inflow of blood from the surface of the body, caused by the local lesions, also gives rise to peritoneal, pleural, and ventricular effusions.

Should the body have been so badly burned as to be charred or even incinerated, the bony portions usually remain in considerable part, and it is possible to determine the sex from the shape of the pelvis, and to estimate the age from the length and development of the bones and by the lower jaw and teeth. Even if largely reduced to ashes, portions of the bones, sufficient to determine their character, can be detected by careful sifting. Special articles of identity are usually to be found among the ashes. Buttons, articles of jewelry, false teeth and filled teeth, discovered, have been sufficient to establish identification. A chemical analysis of the ashes may sometimes afford valuable evidence, in cases of suspected poisoning, with burning to conceal the crime. While volatile and organic poisons may be dissipated by the intense heat, some agents used in poisoning are not so affected, and might be detected.

When the body is not completely roasted and charred, the possibility of the existence of *wounds* should lead to a careful examination for them, and for fractures of the bones; their accidental occurrence, however, must be remembered. If the body be cremated the evidence of previous violence is destroyed, and an opinion upon the subject could not be formed.

The period of time necessary to cremate the body may become an important question in cases in which such cremation has been resorted to for concealing crime. In the "Druse case" it was definitely ascertained that, in less than ten hours, a human body was cremated in a stove by burning with pine shingles.

Was the Burn Ante Mortem or Post Mortem?—It becomes important to decide, in some cases, whether the burns noted are of ante-mortem or post-mortem occurrence. The decision of this question is largely dependent upon the presence or absence of true *blisters*, since vesication is an almost constant lesion in burns occurring during life. The blister is formed by the separation of the cuticle from the derma by the effusion of an albuminous serum, the surrounding skin being of a bright or coppery red color. The occurrence of blisters may be almost immediate or it may be delayed for many hours, according to the occurrence or non-occurrence of a vital reaction. In cases of shock, or of great depression of the vital powers, accompanying insensibility, death may supervene before vesication can appear. The absence of blisters would not, in such case, be a determining factor.

Blisters are more likely to occur when the burn has resulted from the application of steam, a scalding fluid, flame, or by burning clothing, rather than from the application of a highly heated body. In the living body, if the elevated cuticle of the blister be removed, *a bright red base* is exposed; in the dead body, no red base appears. The blister produced during life contains a yellowish, highly albuminous serum.[*] If the blister be unbroken this is present; but if the cuticle be broken evidence of the existence of the blister is found upon the sides and the parts adjacent. The blister produced post mortem usually contains air only, but if its contents are fluid they are not a true serum. The cuticle in such blisters is elevated by the vaporization of the fluids of the tissues beneath it by the heat applied. It is possible in some conditions to produce such blisters immediately after death. Leuret[†] and Champouillon,[‡] succeeded in producing in dropsical subjects, a few hours after death, blisters containing a reddish fluid, slightly albuminous; but such blisters could be distinguished from true blisters produced ante mortem. Wright publishes similar experiences. The experiments of Woodman and Tidy[§] lead them to corresponding conclusions, while Chambert, Taylor,[‖] Jastrowitz,[¶] and others conclude that, while blisters having fluid contents can sometimes be produced within twenty-four hours after death, such blisters lack the essential features characteristic of those produced during life. An extended series of experiments, in this direction, has led the writer to adopt the conclusion that *a true blister cannot be produced post mortem.*

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* Tidy, "Legal Medicine," ii., 99.

A more important anatomical feature of the burn than the blister is the condition of the skin surrounding the burn. The skin of the burned part appears dry and parchment-like, of a dusky red color, and is surrounded by an area of grayish-white skin bounded by a deeply marked *red line.* The general redness of the burn is transient, disappearing under pressure, but the *red line is permanent* and does not disappear under pressure, and remains after death. This *line of redness* is developed during life, and is essentially a vital process, thus becoming of great significance from a medico-legal point of view.[**]

Vesication and the formation of the *line of redness* are vital processes, requiring time for their development; yet the absence of these conditions requires a most careful scrutiny of the circumstances attending the burning, as to the existence of shock or profound insensibility, before the adoption of a decision that the burns noted are post mortem.

In cases of multiple burns upon the same body, the question of simultaneous production can be decided by the presence of the same symptoms in all.

Spectroscopic investigation of the condition of the blood in burns thus far has failed to develop constant or purely characteristic appearances. Lack of uniformity in changes noted, in such examinations, and the limited series recorded have not yielded sufficiently positive results upon which to decide questions which may arise.[††]

Some of the spectroscopic analyses of the blood, in such cases, have shown the presence of dark bands in the spectrum, not encountered in that of normal blood; such bands, however, have not been uniformly noted. Many modifying considerations must be entertained in such examinations, such as the differing intensity of the heat, the length of exposure to it, as well as other elements of variation.

Wertheim[‡‡] calls attention to the increased number of leucocytes and the presence of melanin and hæmoglobin. With these observations, those of Hoppe-Seyler agree. Ponfik,[§§] on the contrary, is doubtful of the constant presence or the significance of these conditions. Seliger and others have noted appearances similar to those described by Wertheim.

The bright color of the blood observed by Falk[‖‖] and others is contrary to that noted by some observers who have described it as being of a dark, venous hue. These differing conditions may, in some cases at least, be explained by the mode of death. When the fatal issue has resulted from suffocation, caused by the deprivation of oxygen and by the respiration of the products of combustion, the color of the blood would be dark or venous; while in case of death by apnœa, induced by an atmosphere containing an excess of carbon monoxide, the color of the blood would probably be bright or arterial.

Spontaneous Combustion.—The possibility of the occurrence of "spontaneous combustion" of the human body has been occasionally discussed, and a number of cases have been popularly reported. Its serious consideration here, as a scientific fact, is not entertained. The term "spontaneous combustion" is a misnomer. The burning of the body cannot be accomplished without contact with fire.

The possibility of an "increased combustibility" of the human body, under certain conditions, has been recently maintained, and that, under such circumstances, the application of flame causes its rapid combustion. Dr. Hava, of New Orleans, has urged the existence of such a condition.[*] His experiments on animals and one or two cases observed in the human subject, apparently sustaining his position, have led him to claim the possibility of "an increased combustibility" of the human body, as the result of a gradual, progressive, and constant accumulation of carbon monoxide for many years, and its consequently rapid combustion on exposure to flame.

Enoch Vine Stoddard.

BURSÆ, LIST OF.—A knowledge of the exact location of bursæ is of great importance with reference to diagnosis. Unfortunately the subject has been somewhat neglected by descriptive anatomists. While some bursæ have received names and are accurately described, others are but seldom mentioned, and authors differ as to their nomenclature. In the following list, which has been carefully compiled from various sources, an endeavor has been made to describe and name all the bursæ which have been found in the human body, omitting only those which are merely accidental. The figures show the situation of the principal bursæ in the most important surgical regions.

HEAD.—*Bursa galeæ capitis.* Between the aponeurosis of the occipito-frontalis and the pericranium, directly over the occipital protuberance.[1] Only in aged subjects.

B. sacculi lachrymalis. Between the lachrymal sac and the internal palpebral ligament.[2] Rare.

B. trochlearis oculi. In the pulley of the superior oblique. Constant.

B. capsulæ oculi. Between the capsule of Tenon and the globe of the eye. Usually imperfect. Hyrtl[3] cites cases of effusion into the sac.

B. circumflexi palati (Rosenmüller). Where the tendon of the tensor palati turns around the hamular process.

Bursæ massetericæ. There appear to be several bursæ between the masseter and the subjacent structures. Rosenmüller mentions one between the two portions of the masseter, and one between the masseter and the external pterygoid. Hyrtl[4] mentions one between the muscle and the temporo-maxillary articulation. Nancrede supposes that these may become continuous, and when inflamed form a cystic tumor reaching to the base of the skull.

B. spinæ sphenoideæ. Hyrtl[5] states that when the temporo-maxillary joint is unusually large a bursa occurs between the spine of the sphenoid and the joint capsule.

B. anguli mandibuli. Subcutaneous over angle of the jaw. Rather rare.

B. sublingualis. Between the tongue and the mucous membrane, outside the genio-glossus. Frequently called Fleischmann's bursa, from its discoverer.[6] Some deny its existence.[7] Tillaux has frequently found it, and believes that acute ranula is caused by a rupture of Wharton's duct into it.[8]

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[*] Kossack: Friederich's Blätt. f. gericht. Med., 1877, Heft iii., 210.
[†] Annales d'hygiène, 1835, ii., 387.
[‡] Annales d'hygiène, 1846, i., 320.
[§] "Forensic Medicine," 1877, p. 886.
[‖] "Medical Jurisprudence," Am. ed., 1880, p. 408.
[¶] Vierteljahrsch. f. gericht. Med., Bd. xxxvi., Heft i., 1880.
[**] Casper: "Forensic Medicine," iv., 299.
[††] Schjerning-Eulenberg's Vierteljahrs. f. gericht. Med., xli., 44.
[‡‡] Wien. med. Presse, 1868, pp. 309-605.
[§§] Berliner klinische Wochenschrift, 1876, No. 17; 1877, No. 46.
"Die Verbrennungen und Verbrühungen."

[*] The New Orleans Medical and Surgical Journal, April, 1894.

B. præmentalis (Fig. 1060). Subcutaneous at lower border of the symphysis of the chin. Quite constant.[9]

NECK.—*B. digastrici posterior* (Rosenmüller). Between the posterior belly of the digastric and the sterno-mastoid.

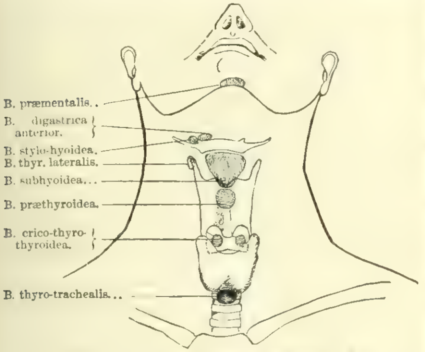

FIG. 1060. The Principal Bursæ of the Neck, in Front.

B. digastrici anterior (Rosenmüller) (Fig. 1060) Where the tendon of the digastric passes through the fascia binding it to the hyoid bone, or through the stylo-hyoid muscle.

B. stylo-hyoidea (Fig. 1060). Under the insertion of the stylo-hyoid and the hyoid bone.

B. suprahyoidea (Verneuil). Between the upper surface of the hyoid bone and the genio-hyo-glossi. Rare.

B. subhyoidea (Fig. 1060). Between the hyoid bone + combined insertion of sterno-hyoid, omo-hyoid, and stylo-hyoid muscles, and the thyro-hyoid membrane. Larger in men than in women. Often called Boyer's bursa.

B. sterno-hyoidea (Rosenmüller). Between the insertion of the sterno-hyoid and the hyoid bone.[10]

B. præthyroidea (Fig. 1060). Between the skin and the upper part of the thyroid cartilage in old subjects. Often wanting.

B. thyroidea lateralis (Gruber[11]) (Fig. 1060). Between the inferior constrictor and the greater cornu of the thyroid cartilage. Found in five cases out of fifty.

B. crico-thyro-thyroidea (Calori[12]) (Fig. 1060). Between the lateral lobes of the thyroid body and the crico-thyroid.

B. thyro-trachealis (Calori) (Fig. 1060). Between the isthmus of the thyroid body and the trachea. Usually single and median; there may be one on either side. Most common when the pyramid of the thyroid body is well developed, especially when it is attached to the hyoid bone.

B. musculi thyroidei. Between the levator thyroidei, when that muscle is present, and the thyroid body. Calori figures one in a case of goitre.

B. omo-hyoidei. Between the sterno-mastoid and the middle tendon of the omo-hyoid. Mentioned by Nancrede, but not generally noticed by authors.

Bb. aortico-tracheales (Calori). Between the aorta and the trachea. A large one extends from the origin of the innominate to the left carotid, and from the upper border of the arch to the bifurcation of the trachea. A second one is described as posterior to this, also a small one which extends between the left carotid and the trachea. Some one of these was found in thirteen out of forty examinations. If the pericardium extends upward, the large aortico-tracheal bursa is small.

B. vertebræ prominentis. Between the skin and the spinous process of the seventh cervical vertebra. Nancrede states that this is quite large, and may inflame from pressure of a heavy overcoat.

TRUNK.—*B. subclavia* (Rosenmüller). Within the fibres of the rhomboid ligament.[13] Not constant. May simulate a costo-clavicular articulation, of which, indeed, it seems to be the beginning.

B. submammaria. Between the mammary gland and the pectoralis major. Rare, but interesting, as it may be involved in a case of mammary abscess.

B. anguli sterni. Subcutaneous over the angle between the first and second pieces of the sternum. In carpenters and cabinetmakers.

B. hyper-xiphoidea. Subcutaneous over xiphoid cartilage. Usual in shoemakers and rachitic children.

B. suprapubica. Beneath the pubic attachment of the rectus abdominis. Duval[14] reports that inflammation of this has been known to occur as a sequel to croupous pneumonia. Not mentioned by authorities generally. Schreger mentions a subcutaneous bursa at the side of the suspensory ligament of the penis.

B. costæ primæ. Between the muscles of the back and the tuberosity of the first rib. Mentioned by Nancrede. It is probably rare, as the principal authorities omit it.

B. sacralis (Luschka). Over spinous process of fourth or fifth sacral vertebra, or over the articulation of the sacrum and coccyx. Usual in old subjects.

B. coccygea (Luschka). Between tip of coccyx and sphincter ani. Common.[15]

B. phrenico-hepatica anterior (von Brunn[16]). Between the left lateral ligament of the liver and the under surface of the diaphragm in front. Found in 31 cases out of 64. Its enlargement might simulate a diaphragmatic hernia.

B. phrenico-hepatica posterior (von Brunn). Between the same structures behind. Found in 2 cases out of 64.

SHOULDER.—*B. trapezii.* Between the aponeurotic part of the trapezius and the base of scapular spine (3 times in 12, Synnestvedt).

B. latissimi dorsi. Between the latissimus dorsi and the inferior angle of the scapula. Recent observers (Henle, Heineke, Synnestvedt) do not find this.

B. spinæ scapula;

B. supracromialis. These are subcutaneous, found in those who carry burdens.

B. infrascapularis. Between the inferior angle of the scapula and the chest wall. Usually between subscapularis and serratus magnus. May be of considerable size, and by crepitation, when inflamed, simulate crepitant râles or pleuritic fremitus.[17]

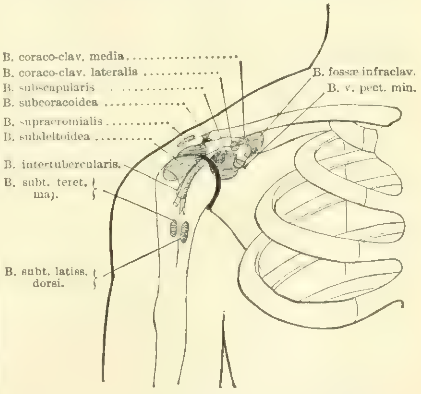

FIG. 1061.—The Principal Bursæ about the Shoulder.

B. subdeltoidea (Fig. 1061). Between the under surface of the acromion + structures arising therefrom (lateral portion of coraco-acromial ligament, deltoid muscle) and the capsular ligament of the shoulder joint.[18] Constant. Many authors describe the upper part of this bursa separately as *B. subacromialis.* This portion may be separate, but it usually communicates, and the whole should be considered as a single large multilocular bursa. Rarely communicates with the joint. Its inflammation may simulate dislocation of the biceps tendon (Nancrede).

B. coraco-brachialis (Monro). Between the lateral part of the subscapularis and the short head of the biceps + coraco-brachialis. Sometimes communicates freely with B. subdeltoidea. Also known as B. subcoracoidea.

B. coraco-brachialis minor (Gruber). Under a rare muscle, which arises from the anterior and internal part of the coracoid process.

B. fossæ infraclavicularis (Gruber) (Fig. 1061). Between two layers of the coraco-clavicular fascia (costo-coracoid membrane), in front of the coracoid process. Frequent (1 in 3), more common in women.

B. coraco-clavicularis media (Gruber) (Fig. 1061). Between the conoid and the trapezoid ligaments. Frequent (1 in 2). May simulate a coraco-clavicular articulation.

B. coraco-clavicularis lateralis (Gruber) (Fig. 1061). Between the coracoid process and the trapezoid ligament. Occasional (1 in 5).

B. subtendinea pectoralis minoris. Under insertion of pectoralis minor. Rare (1 in 30 or 40, Gruber).

B. vaginalis pectoralis minoris (Gruber) (Fig. 1061). Around tendon of pectoralis minor. Rare (1 in 10).

B. subscapularis (Fig. 1061). Between the subscapularis and the neck of the scapula. Constant. It always communicates with the joint, and may properly be considered as a diverticulum of the capsule.

B. subcoracoidea (Gruber) (Fig. 1061). Between the upper edge of the subscapularis and the B. subscapularis.[19] Found 10 out of 12 times (Synnestvedt); in two of these cases it communicated with B. subscapularis.

B. subtendinea subscapularis (Synnestvedt). Between the tendon of the subscapularis and the capsule (2 times in 18).

B. intertubercularis (Henle[20]) (Fig. 1061). Surrounding the tendon of the long head of the biceps in the groove of the humerus. Constant. Always communicates with joint cavity, and should be considered as a diverticulum of the capsule.

B. infraspinata (Rosenmüller). Between upper edge of infraspinatus and scapular spine (2 in 3, Synnestvedt).

B. subtendinea infraspinata. Between tendon of infraspinatus and capsule (4 in 14, Synnestvedt).

B. subtendinea teretis minoris (Gruber). Under the tendon of the teres minor. Rare.

B. subtendinea teretis majoris (Fig. 1061). Between the tendon of insertion of the teres major and the latissimus dorsi. Constant.

B. subtendinea latissimi dorsi (Fig. 1061.) Between the tendon of the latissimus dorsi and the humerus.

B. subtendinea pectoralis majoris. Between tendon of pectoralis major and B. intertubercularis + tendon of latissimus dorsi (4 in 12, Synnestvedt).

B. intermuscularis pectoralis majoris (Synnestvedt). Between the clavicular and thoracic portions of the muscle.

ELBOW.—*B. radio-bicipitalis* (Rosenmüller). Between the tendon of the biceps and the inner surface of the radius. Constant, often double.

B. ulno-radialis (Jancke). Between the tendon of the biceps + radial tuberosity and outer surface of ulna + muscles of that region. Of considerable size. Frequent (1 in 4, Gruber; 3 in 6, Synnestvedt).

B. subtendinea brachialis. Between the tendon of insertion of the brachialis anticus and the coronoid process. Rare. The older anatomists (Fourcroy, Jancke, Koch) describe a bursa between the brachialis anticus and the interosseous ligament.

B. flexoris digitorum sublimis (Gruber). In the tendon of origin of the flexor sublimis, or between it and the pronator radii teres. Very rare (1 in 200).

B. palmaris longi. Between the origin of the muscle and the joint capsule. Very rare.

B. subcutanea olecrani (Camper). Between the skin and the periosteum of the olecranon. Constant in adults.

B. subtendinea olecrani. Above the olecranon, and in front or at the side of the triceps tendon. Frequent (3 in 5); constant in old subjects.

B. intratendinea olecrani. Within the tendon of the triceps. Quite frequent (7 in 12, Synnestvedt).

B. humero-tricipitalis. Between the anterior surface of the triceps and the fat covering the lower end of the humerus. Rare (1 in 12, Synnestvedt).

B. retro-epitrochlearis. Between the triceps + ulnar nerve behind, and the posterior surface of the internal condyle + median surface of capsule in front. Very rare.

B. anconei (Rosenmüller). Between the anconeus and the capsule (1 in 4 or 5). May communicate with B. extensoris carpi ulnaris or with joint (Henle).

B. epicondyli (Schreger). Between the skin and the external condyle of the humerus. Rare (1 in 60).

B. extensoris carpi ulnaris (Jancke). Under origin. May extend under the extensor communis. Frequent (1 in 3 or 4). May communicate with the joint and also with B. anconei.

B. extensoris carpi radialis brevioris (Monro). Between the common origin of the extensor carpi radialis brevior + the extensor communis digitorum and the head of the radius (1 in 6 or 7).

B. epitrochlei (Schreger). Between the skin and the inner condyle of the humerus. Rather frequent (1 in 5).

WRIST AND HAND.—*B. ulnaris subcutanea.* Over styloid process of ulna. Not constant (3 in 11, Synnestvedt).

B. radialis subcutanea. Over styloid process of radius. Rather rare.

B. dorsalis carpiea subcutanea. Schreger found this in 2 cases.

B. vaginalis extensoris carpi ulnaris (Fig. 1062). A small sheath. Reaches to the base of metacarpale V.

B. v. extensoris minimi digiti (Fig. 1062). A small and separate sheath.

B. v. extensorum communis et indicis (Fig. 1062). Large. Extends farther toward the fingers on the ulnar side.

B. v. extensoris longi pollicis (Fig. 1062). Runs obliquely across the next.

B. v. extensorum carpi radialorum (Fig. 1062). In groove on back of radius. Single above, divides below.

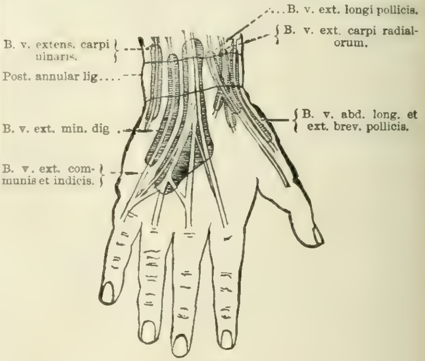
B. v. ext. longi pollicis.
B. v. ext. carpi radialorum.
B. v. extens. carpi ulnaris.
Post. annular lig....
B. v. abd. long. et ext. brev. pollicis.
B. v. ext. min. dig
B. v. ext. communis et indicis.

FIG. 1062.

B. subtendinea extensoris carpi radialis longioris. Under the tendon at its insertion into metacarpale II. (4 in 20, Synnestvedt).

B. subtendinea extensoris carpi radialis brevioris. Under the tendon at its insertion into metacarpale III. (18 in 20, Synnestvedt).

B. vaginalis abductoris longi et extensoris brevis pollicis (Fig. 537).—Surrounds these tendons from the dorsal surface of the radius to the outer edge of the wrist.

B. subtendinea flexoris carpi ulnaris (Fig. 1063). Under the tendon at its insertion into pisiform (6 in 30 Synnestvedt).

B. tendinosa ulnaris (Michon) (Fig. 1063). The usual arrangement of this extensive sheath is to surround the tendons of both the superficial and deep flexors as they lie in the wrist and palm, sending a diverticulum downward upon the tendons of the little finger. Schüller[21] describes this bursa as double, the sheath for the tendons of digits IV. and V. being separate from those of digits II. and III. Holden[22] reports a case in which this bursa communicated with the wrist joint. It does not usually communicate with the radial bursa,[23] but many varieties are found.[24]

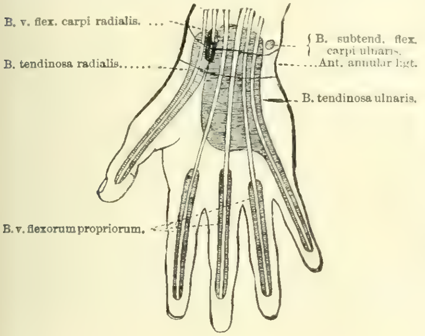
B. v. flex. carpi radialis.
B. subtend. flex. carpi ulnaris.
B. tendinosa radialis.
Ant. annular lgt.
B. tendinosa ulnaris.
B. v. flexorum propriorum.

FIG. 1063.

B. vaginalis flexoris carpi radialis (Fig. 1063). In the groove of the trapezium.

B. tendinosa radialis (Michon) (Fig. 1063). Extends from an inch above the anterior annular ligament to the base of the second phalanx of the thumb, upon the tendon of the flexor longus pollicis.

Bb. dorsales subcutaneæ. Between the skin and the extensor tendons on the ulnar side over the metacarpophalangeal joint (Synnestvedt found them in digit I., 40 per cent.; digit II., 53 per cent.; digits III. and IV., 66 per cent.; digit V., 27 per cent.).

Bb. dorsales subtendineæ.—Between the tendons and the capsules of the metacarpo-phalangeal joints. Quite constant. Frequently communicate with joint. When not found a diverticulum of capsule takes the place (Theile, Synnestvedt).

Bb. volares articuli-metacarpo-phalangei. Between the skin + subcutaneous fat and the flexor tendon with its fibrous sheath. Found by Schreger in all the digits, by Synnestvedt only in digits I., II., and III.; most frequent in digit III.

Bb. volares phalangis primæ. Between the skin and subcutaneous tissue and the flexor tendon with its sheath in front of the first phalanx. Found by Synnestvedt in but two instances, in digit II. and digit III.

Bb. vaginales flexorum propriorum (Fig. 1063). Special sheaths for the flexor tendons of digits II., III., and IV.

Bb. intermetacarpo-phalangea. Between the heads of metacarpales II., III., IV., and V.

Bb. interossea. Between the tendons of the interossei muscles and the metacarpo-phalangeal joints. Gruber[25] finds two sets of these, one under the part of the tendon that extends to the dorsal aponeurosis, the other under the part which communicates with the phalanx.

B. metacarpea ulnaris (Synnestvedt). Between the skin and the head of the fifth metacarpal. Found in 8 out of 15 cases.

Bb. phalangea dorsales. Over the articulations. Quite constant over the first series; less so over the second.

HIP.—*B. iliaca anterior.* Subcutaneous over the anterior superior spine of the ilium.

B. subiliaca (Hyrtl). Under the tendon of the iliopsoas, covering the ilio-pectineal tubercle, the anterior surface of the pubis, and the capsule of the hip joint. This large and constant bursa is sometimes multilocular and frequently (6 in 14, Synnestvedt) communicates with the hip joint.

B. subtendinea iliaci. Between the tendon of insertion of the ilio-psoas and the femur. Not constant.

B. subtendinea pectinei. Between the insertion of the pectineus and the femur + lowest fascicles of the iliacus. Frequent (8 in 14, Synnestvedt).

B. trochanterica superficialis. Subcutaneous over the trochanter major. Usually small, but sometimes multilocular. Rather frequent (4 in 13, Synnestvedt).

B. trochanterica profunda. Between the tendon of the gluteus maximus and the posterior and external portions of the great trochanter. Large and constant; frequently multilocular.

Bb. gluteo-femorales. One or more between the tendon of the gluteus maximus and the femur. Quite constant.

B. gluteo-fascialis. Between the tendon of the gluteus maximus and the origin of the vastus internus. Constant.

B. glutei medii anterior. Between the anterior portion of the tendon of the gluteus medius and the great trochanter. Nearly constant (12 in 15, Synnestvedt).

B. glutei medii posterior. Between the posterior portion of the tendon of the gluteus medius and the pyriformis. Usual (10 in 15, Synnestvedt).

B. glutei minimi. Between the gluteus minimus and the anterior surface of the great trochanter. Large and nearly constant (14 in 15, Synnestvedt).

B. supra-acetabularis. Between the reflected tendon of the rectus and the upper edge of the acetabulum (5 in 16, Synnestvedt).

B. pyriformis. Under the distal insertion of the muscle Infrequent (3 in 12, Synnestvedt).

B. gemellorum (Synnestvedt). Between the gemelli and the joint capsule. Found once only. It communicated with B. circumflexa.

B. ovalis obturatoris interni. Between the tendon of the obturator and the gemelli. Rather frequent (5 in 13, Synnestvedt). Communicates sometimes with B. circumflexa.

B. circumflexa obturatoris interni. Between the muscle and the lesser sciatic notch.

B. subtendinea obturatoris interni. Between the tendon and the capsule of the hip joint. Rare. May communicate with last (Quain).

B. obturatoris externi (Synnestvedt). Between the obturator externus and the joint capsule. Infrequent (2 in 18).

B. quadrati femoris. Between the quadratus femoris and the trochanter minor + tendon of ilio-psoas. Constant.

B. subcutanea tuberis ischii. This is described by some (Hyrtl, Nélaton) as directly under the skin over the tuberosity of the ischium. It is probably rare. The three following are often mistaken for it:

B. musculi glutei in tubere ischii. Between the lower border of the gluteus maximus and the tuberosity of the ischium (5 in 12, Synnestvedt.)

B. semitendinoso-bicipitalis in tubere ischii. Between the tendon of the united semitendinosus and biceps and the tuberosity. Constant.

Bb. semimembranosæ in tubere ischii. Two of these are found between the tendon of the semimembranosus and the quadratus femoris. One is quite constant (9 in 12), the other infrequent (2 in 12, Synnestvedt).

B. iliaca posterior. Subcutaneous over the posterior superior spine of the ilium.

KNEE.—*B. condyli interni;*

B. condyli externi. Subcutaneous bursæ over the projecting condyles (Figs. 1064 and 1065).

B. præpatellaris subcutanea (Fig. 1064). In the subcutaneous connective tissue in front of the patella. This is quite common (18 in 20, Synnestvedt; 165 in 400, Gruber), and is usually confounded with the next. It may be of considerable size.

B. præpatellaris subfascialis. Between the fascia in front of the patella and the aponeurosis of the extensors. Not so frequent (9 in 20, Synnestvedt; 23 in 400, Gruber).

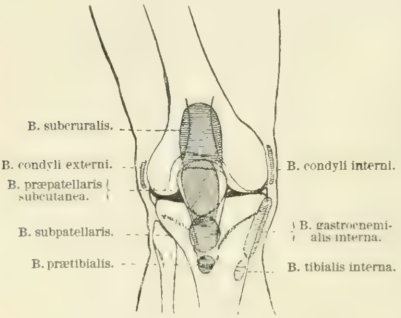

FIG. 1064.—The Principal Bursæ in Front of the Knee.

B. præpatellaris subaponeurotica. Between the aponeurosis and the anterior surface of the patella. Found in 9 out of 20, Synnestvedt; 23 in 400, Gruber; 10 out of 12, Schreger. This division of the præpatellar bursæ is that of Gruber. The three here described rarely coexist, and when they do, they usually communicate.

B. subcruralis (Fig. 1064). Between the tendon of the extensor quadriceps and the lower part of the anterior surface of the femur above the patella. This is always present, and invariably communicates with the joint, except occasionally in very young children.

B. intermuscularis extensoris cruris. Between the tendons of rectus and the cruræus. About an inch above the patella. Rare (2 in 55, Synnestvedt).

B. patellaris externa. Between lateral expansions of the tendons of the quadriceps femoris and the patella. Rare.

B. patellaris lateralis interna. In a similar situation on the inner side. Synnestvedt mentions two varieties, one superficial and one deeper.

B. præligamentosa. Between the fascia and the ligamentum patellæ. (Found by Synnestvedt in 6 out of 15.)

B. prætibialis (Fig. 1064). Between the fascia and the tuberosity of the tibia. Usual in old subjects.

B. subpatellaris (Fig. 1064). Between the ligamentum patellæ and the anterior surface of the tibia. Constant and large. May occasionally communicate with the joint, though Synnestvedt has never seen this, and thinks the reported cases erroneous.

B. subtendinea sartorii. Between the tendon of the sartorius and the internal condyle of the femur. Rather rare (2 in 15, Synnestvedt).

B. sub ligamento interno (Synnestvedt). Between the internal lateral ligament and the capsule (11 out of 21).

B. tibialis interna (Fig. 1064). Between the expansion of the lower internal ham-string tendons (semitendinosus, gracilis, sartorius), and the long internal lateral ligament.[26] Constant. It occasionally blends with B. gastrocnemialis interna, and through that communicates with the joint.

B. tibialis subcutanea (Schreger). Subcutaneous over upper end of tibia. Not found by Gruber or Synnestvedt.

B. tendinis poplitei. Between the external lateral ligament and the tendon of the popliteus. Not constant (5 in 16, Synnestvedt). Occasionally communicates with joint.

B. tendinis bicipitis (Fig. 540). Between the external lateral ligament and the tendon of the biceps. Nearly constant (21 in 26, Synnestvedt; 191 in 200, Gruber). It occasionally communicates with the joint. The external popliteal nerve is in relation to it.

B. subtendinea tensoris fasciæ latæ (Synnestvedt). Between the ilio-tibial band and the capsule. Found in 3 out of 19, once communicating with joint.

B. fibularis subcutanea (Schreger). Subcutaneous over upper end of fibula. Not found by Gruber or Synnestvedt.

B. supracondyloidea interna (Fig. 1065). Between the inner tendon of the gastrocnemius and the femur. Nearly constant. May communicate with joint.

B. gastrocnemialis interna (Figs. 1064 and 1065). Between the inner head of the gastrocnemius and the semimembranosus. It is behind the internal condyle and over the neighboring capsule. Large and constant. Sometimes multilocular. In adults it usually communicates with the joint. Synnestvedt describes the lower part of this as a separate bursa, under the name of *B. semimembranoso gastrocnemialis.*

B. semimembranosa (Fig. 1065). Between the expansion of the semimembranosus tendon and the inner condyle of the tibia. Usually closed. Constant.

B. gastrocnemialis externa. Between the external head of the gastrocnemius and the capsule. Rare.

B. bicipito-gastrocnemialis. In the popliteal groove between the prominence of the sesamoid bone in the head of the gastrocnemius and the biceps tendon. Very rare.

B. poplitea (Fig. 1065). Between the popliteus and the joint capsule + external tuberosity of tibia. This always communicates with the joint, and is properly a diverticulum of the capsule, occasionally (1 in 10, Lenoir) it also communicates with the cavity of the superior tibio-fibular articulation.

ANKLE AND FOOT.—*B. malleoli externa ;*

B. malleoli interna. Subcutaneous over the malleoli. Not constant. External more frequent.

B. vaginalis extensoris longi digitorum ;

B. v. extensoris longi hallucis ;

B. v. tibialis antici (Fig. 1066). Around the tendons of these muscles. Not infrequently the sheath of the extensors extends somewhat higher up than is shown in the figure.

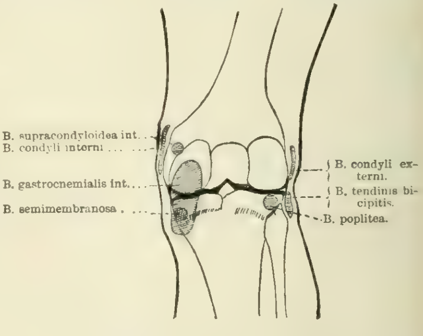

FIG. 1065.—The Principal Bursæ Behind the Knee.

B. sinus tarsi (Gruber). Between the fascia which binds down the extensor longus digitorum and the head of the astragalus. Quite frequent (5 in 12, Synnnestvedt; 97 in 174, Gruber). May communicate with joint.

Bb. sub musculo pediæo. Under the extensor brevis digitorum. Usually two. Found by Synnestvedt 2 in 16.

B. tarsiea subcutanea (Schreger). On dorsal surface of foot.

B. vaginalis tibialis postici (Fig. 1067). Surrounds the tendon as it lies back of the internal malleolus.

B. v. flexoris longi digitorum ;

B. v. flexoris longi hallucis (Fig. 1067). Surround the tendons behind the internal malleolus and extend into the sole.

B. postcalcanea superficialis. Between the tendon and the deep fascia. Not constant.

B. postcalcanea profunda (Fig. 1067). Between the tendon and the posterior surface of the calcaneum. Constant. Has cartilage on two of its walls, viz., over the bone, and a thin layer coating the anterior surface of the tendon.

B. subcalcanea (Lenoir[27]). Between the inferior surface of the calcaneum and the plantar fascia. Constant.

B. subtendinea tibialis antici (Fig. 1066). Under the tendon at its insertion upon cuneiforme I. (5 in 12, Synnestvedt).

Bb. abductoris minimi digiti (Synnestvedt). One between the abductor and the sesamoid bone of the peroneus longus; another between the muscle and the tuberosity of metacarpale V. Rare.

B. subtendinea peronei tertii (Hyrtl) (Fig. 1066). Under the tendon at its insertion upon head of metacarpale V. Not constant.

B. subtendinea extensoris longi hallucis. Between the tendon and the head of metacarpale I. Small and rather rare.

B. vaginalis anterior extensoris longi hallucis (Fig. 1066). Over metatarso-phalangeal joint I. About one inch long.

B. v. peronei. Sheathes the peroneal tendons behind the external malleolus. Single in the middle, it divides above and below.

Bb. dorsales subcutaneæ. Several of these are described by Schreger and Synnestvedt. One over cuneiforme I., one over head of metacarpale I., and occasionally over other projections.

Bb. dorsales subtendineæ (Synnestvedt). These occur in similar situations as those of the hand, and agree with them in form and size.

B. vaginalis peronei longi. Sheathes the tendon as it lies in the groove of the cuboid. A small bursa is sometimes found under the tendon where it turns around the outer side of the cuboid, and another under its insertion upon metatarsale I.

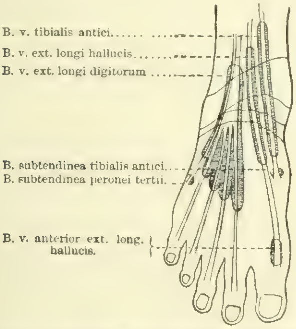
B. v. tibialis antici
B. v. ext. longi hallucis
B. v. ext. longi digitorum
B. subtendinea tibialis antici
B. subtendinea peronei tertii
B. v. anterior ext. long. hallucis

FIG. 1066.—Synovial Sheaths on Back of Ankle and Foot.

Bb. plantaris metatarso-phalangei (Schreger). These occur at the articulations.

B. plantaris in capitulo ossis metatarsi I. (Lenoir);

B. plantaris in capitulo ossis metatarsi V. (Lenoir). These are well-known bursæ between the skin and the points of greatest pressure.

Bb. intermetatarso-phalangeæ. These are usually found in old subjects, between the toes, in the region of the metatarso-phalangeal joints. The three inner are most constant (No. 1, 95 per cent.; No. 2, 98 per cent.; No. 3, 95 per cent.; No. 4, 28 per cent., Gruber). Occasionally communicate with joints.

Bb. interossea. Between the interossei and the metatarso-phalangeal joint. Rarely communicate.

Bb. lumbricalium. Under the lumbricales and laterally to them. Rare.

B. abductoris minimi digiti. Between the abductor of the little toe and the head of metatarsale V. Rare (1 in 14, Synnestvedt).

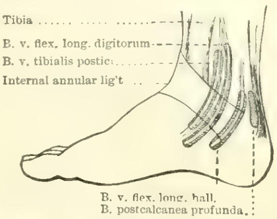

FIG. 1067.—Synovial Sheaths of Inner Side of Foot.

Bb. phalangea dorsales (Schreger). These are not so constant as those of the hand.

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Frank Baker.

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[3] Topogr. Anatomie, 7 Aufl., i. 225.

[4] *Op. cit.*, i., 415.

[5] *Op. cit.*, i., 363.

[6] Häser's Report, ii., 6, 1841.

[7] Sappey: Anat. Descriptive, second edition, iv., 67.

[8] Tillaux: Anatomie topographique, third edition, 320. *Cf.* C. O. Weber in Virchow's Archiv. vi., 511, Berlin, 1854.

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[10] Luschka: Anat. des menschl. Halses, 140.

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[14] Gazette des Hôpitaux, Mai, 1854, p. 250. Nancrede cites this with approval.

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BURSÆ. (SURGICAL.)—The pathological lesions of bursæ that demand surgical relief are those which follow traumatism and various forms of acute and chronic inflammation. Of the large number of bursæ and synovial or bursal sacs in the body, a certain few, by reason either of their situation or of their structure, are especially prone to cause trouble. These alone will be mentioned in this article, although the lesions discussed in connection with them may also be found in other less well-known bursæ. The affections of other synovial sacs, which are really only larger bursæ, will not be considered here because their importance demands that they be separately enumerated. Such are the synovial linings of joints, and the serous linings of the larger cavities existing in the skull, spinal column, thorax, abdomen, and scrotum.

ACUTE LESIONS.—*Traumatism.*—A fall upon the elbow or knee may cause a contusion of the subcutaneous bursa marked by pain and tenderness, with only slight redness, heat, and swelling. Often the traumatism will give rise in addition to an effusion of serum and sometimes to a hemorrhage into the bursal sac. Under such circumstances there will be, in addition to the signs noted above, that of a well-marked rounded tumor, not attached to the skin. If the bursa is filled with serum, it will be exquisitely fluctuating, though less so if filled with blood.

Treatment.—The affected part should be kept quiet even though to accomplish this end splints or rest in bed are necessary. A mildly antiseptic light wet dressing should be applied, and covered with either cracked ice or a hot-water bag. When the pain and cutaneous swelling have subsided, a flannel bandage, or straps of rubber plaster, will hasten the absorption of serum from the bursal sac.

If rest and pressure do not suffice for the absorption of the serous contents, the latter may be evacuated and pressure again applied. If the sac refills, it may be again emptied and then partly filled with iodine or carbolic acid according to the plan of treatment for hydrocele; or it may be excised.

If a small blood clot exists, similar treatment, *i.e.*, by cold, rest, and pressure, is justifiable. If the clot is of considerable size, it is better to make a short incision, remove the clot, suture the sac and skin, and apply pressure so that the walls of the sac shall remain in contact. If the surgeon is not absolutely sure of his asepsis, he may leave in a drain of six threads of silkworm gut for two days.

Internal Traumatism.—Another form of traumatism occurs from within, that is, through injury of the serous surfaces by the overuse of muscles. As a result the bursal sac becomes sore or distended with fluid, or the serous membrane becomes dry and its surfaces crepitate when they slip on each other. As illustrations of these three types of mild inflammation may be mentioned a bunion which has become sore from a long walk, the distention of the bursa under the tendo Achilles from the same cause, and the crepitation of the extensor tendons of the fingers and hand but especially those of the thumb, a condition which is often produced if a man who has been idle for some weeks starts in energetically at moving furniture or engages in some other hard labor. The swelling and tenderness will be distinct though slight, but the chief symptom will be a fibrinous creaking felt along the course of the tendons when the least motion is imparted to the hand. Sometimes, when the patient has been asked to move the hand a few times in order to demonstrate this symptom, it will entirely disappear.

Treatment.—The treatment of lesions due to traumatism from within does not essentially differ from that of lesions due to traumatism from without. If pain is a prominent symptom, and there is little swelling, the application of iodine, either in the form of the tincture or in that of an ointment, may give relief. In the case of crepitating tendons, a few days' rest of the hand will effect an entire cure; but the patient should be warned against a too speedy return to hard work.

Infection.—Traumatism may produce or be followed by a much more serious condition than those thus far considered, namely, infection. This may be direct and obvious, as when the wound opens into the prepatellar bursa; or indirect as when the germs introduced by a pin-prick in the finger find their way into the serous sacs about the flexor tendons. In both instances more or less cellulitis will follow together with a collection of seropurulent fluid in the cavity of the bursa. Pus may also accumulate outside of the bursal sac; for example, in the hand an abscess, starting in infection in the sheath of the flexor tendons, may point posteriorly between the heads of the metacarpal bones. Under such conditions an anterior incision to open the sheath, as well as a posterior one to open the point of the abscess, will usually be required. This infection of a digital tendon sheath is a very common one and bears the popular name of felon, which see.

Treatment.—If the existence of pus is uncertain in any of these infective cases, rest and a wet antiseptic dressing are permissible. The patient should be kept under close observation, and if the process does not improve in a day, or if signs of accumulation of pus appear, a suitable incision should be made. A *suitable incision* is one which relieves the tension, evacuates the accumulated pus, and allows the escape of pus yet to be formed. The mere pricking of a bursa full of pus, and the cutting of every felon clear to the bone, are both examples of bad workmanship. And drainage requires judgment no less than the incision. The comfort of the patient and the rapidity of his recovery are best provided for by a wet gauze dressing. If the incision has been properly made, and the walls of the bursa have been kept apart by gauze for a few days until granulation has begun, the gauze may soon after be removed from the bursal cavity without danger of pocketing, if only drainage is facilitated by a constant moist dressing. For this purpose nothing is better, and scarcely anything cheaper, than one-per-cent. creolin solution. The gauze may be wet with this before it is applied and after that kept wet with plain cold water. Such a dressing will keep sweet two or three days if necessary.

CHRONIC LESIONS.—*Repeated Traumatism.*—Repeated slight injuries may produce chronic inflammation of a bursa, with accumulation in its cavity of a serous or mucoid fluid, according to the character of the bursal lining. Thus in the bursæ overlying the olecranon and patella, the accumulated fluid is usually viscid,—glairy. The content of a ganglion may be of the same nature.

The elbow and knee are so exposed to injuries of all sorts that they are often the seat of occupation diseases, and hence the names which have been given to chronic bursitis in these regions—miner's elbow, and housemaid's knee. These lesions are by no means, however, confined to these two classes of workers.

The bursa gastrocnemio-semimembranosa sometimes fills with fluid as the result of a sudden strain, but the trouble is more often chronic than acute. The patient suffers from moderate disability and consults a doctor in reference to a smooth tumor lying to the outer side of the popliteal space. The symptoms are plain enough if one has the lesion in mind, but unfortunately a mistaken diagnosis is often made in these cases.

Another chronic bursitis with accumulation of serous or mucoid fluid is usually found in connection with a joint, sometimes in connection with a tendon sheath, and is called a ganglion. It presents itself as a small rounded tumor, tense, elastic, free from the normal skin, but only slightly movable on the deep parts. When cut down upon the sac can be readily freed superficially and at the sides, but its base is intimately associated with the fibrous capsule of the joint, or the tendon sheath, and its cavity may or may not open freely into the cavity of the normal structures. It is still a disputed point whether a ganglion is a bursal outgrowth from the lining of a joint or tendon sheath, or is a fibrous tumor, in which a cavity has subsequently formed and has then opened into the preformed synovial cavity of joint or tendon.

Treatment.—The old treatment of a ganglion was to crush it by a sharp blow with a heavy book, and to apply and keep up pressure by a bandage. This treatment will often result in cure in a recent case, but often too, owing to the thickness of the wall of the ganglion, rupture does not follow the blow. Often, too, the sac refills.

The certainty of aseptic excision of such tumors has rendered the method above described obsolete. When the skin has been cleansed and anæsthetized, an incision should be made over the crest of the ganglion parallel to the long axis of the limb. It should extend one-third inch beyond the edges of the tumor. The sac should be freed from the skin and at the sides before it is cut into. But nothing is gained by its removal entire, and as the operation is made more difficult by this plan of action, it should not be followed, but the sac, when freed laterally, should be split open and emptied. Any communication with joint or tendon sheath will then be manifest, and the base of the sac may be easily and surely removed. If there is a distinct neck it may be ligated, so as to close the cavity of the joint, or the joint may be closed with a suture, or allowed to close of itself. The wound should be carefully sutured, and ought to heal quickly without drainage.

Of course there can be no thought of "breaking" and "scattering" a chronically distended patellar or olecranon bursa. All such should be excised. The practice of making an incision and allowing the sac to granulate uselessly delays the time of complete recovery in non-suppurative cases. It is difficult to anæsthetize the base of an olecranon or patellar bursa, so intimate is its attachment to the periosteum. Hence, unless the patient is ready to stand some pain, it is wise to give a general anæsthetic.

Productive Inflammation.—Sometimes the chronic inflammation of a bursa is of the productive type, and as a result the inner lining of the capsule thickens until the cavity is in great part obliterated, its place being taken by more or less recent fibrous tissue. It is useless to attempt the absorption of such a mass. The whole tumor should be excised and the wound sutured. This form of bursitis is most commonly found in the prepatellar bursa.

Tuberculous Inflammation.—Bursæ are very subject to tuberculous inflammation. In a certain number of cases in which no history of injury exists a bursa, or more often the synovial sheath, will gradually swell up and become fluctuating. When opened the sac will be found to contain serous or mucoid fluid, and often a large number of rice bodies. The contents are similar to those of a tuberculous joint in which the trouble began in the synovial lining and has not yet progressed to the destruction of bone.

In some of these chronic cases the clinical and bacteriological examination make the diagnosis of tuberculous synovitis an easy one; but it by no means follows that every lesion of this sort is tuberculous; even the microscopical character of some chronically inflamed bursæ is in bitter controversy. That is a question, however, which the surgeon may well leave to the pathologist.

Treatment.—There is only one satisfactory method of handling these cases—by excision. If the synovial sacs are affected the complete removal of every bit of inflamed tissue is out of the question. Still if a major portion be removed nature may do the rest. Even though the tendons be widely exposed by the removal of the diseased tissue, they may remain perfectly movable if the wound heals primarily. In general the results which follow operation upon the lesser synovial sacs are of a favorable character.

Edward Milton Foote.

BURSERACEÆ.—A small, but rather important family of some sixteen genera, and about two hundred species, distributed through all tropical and some sub-tropical regions. A few fruits are somewhat eaten (Protium), and some of the seeds yield useful fixed oils. The principal value of the family resides in its numerous gum resins and oleo-resins, which have from the earliest times been used for incense and recognized as important articles of commerce. The best known of them are myrrh, bdellium, olibanum, and elemi, which represent the constituents and properties of the family.

Henry H. Rusby.

BUTTERNUT. JUGLANS.—"The bark of the root of *Juglans cinerea* L. (fam. *Juglandaceæ*), collected in the autumn," U. S. P. The butternut is a medium-sized tree, with short, freely branching trunk and a light foliage of pinnate leaves. The flowers are monœcious: the staminate, in lateral drooping catkins; the pistillate few together in terminal clusters. It is a widely distributed tree, growing in the middle latitudes of North America, furnishing a useful cabinet wood, edible fruit, and a fair dyeing material. The description of the Pharmacopœia is poor, and applies rather to the stem bark. The bark occurs in large quills or curved pieces, about one-quarter of an inch thick. It is of a dark chocolate-brown throughout, the outer surface developing a reddish tinge in time. The outer surface is very little, if at all, fissured or scaly, but is somewhat warty. The inner surface is shreddy with partly detached fibre, in autumn-collected bark, but smooth if collected during the spring or summer. The fracture is weak and soft, but somewhat fibrous, and delicately checkered. It has a feeble odor and a bitter, acrid taste.

It contains a little tannin and volatile oil, fourteen per cent. of fat and a large amount of *juglon*, *nucin*, or juglandic acid, which crystallizes in deep yellow needles and is the active constituent.

ACTION AND USE.—Butternut is a mild cathartic, operating, usually, without pain or irritation, well adapted to continuous administration, and worthy of more frequent use than is made of it. Dose, 1 or 2 gm. (gr. xv. ad xxx.). An extract, extractum juglandis—dose, 3 to 6 dgm. (gr. v. ad x.)—is the only preparation.

ALLIED PLANTS.—*Juglans regia* Linn. is the European walnut (*Noyer commun*, Codex Med.); its leaves are the *Folia Junglandis* of the German Pharmacopœia; its oil, the walnut oil of the market. The rind of the green fruits is collected and dried for a stomachic and vermifuge. It contains the *juglon* (*nucin*) above mentioned. The leaves are used for "scrofula, rickets," etc.

Juglans nigra, the black walnut, has probably similar properties to those of butternut.

Henry H. Rusby.

BUTTERWORTH'S MINERAL SPRING.—Kent County, Michigan.

POST-OFFICE.—Grand Rapids. This spring is located on Huron Street, in the city of Grand Rapids. Adjoining is a commodious bath-house, with suites of rooms on separate floors for ladies and gentlemen (Walton). The analysis is by Dr. S. P. Duffield.

Solids.	Grains.
Sodium bicarbonate	5.00
Calcium bicarbonate	8.34
Magnesium bicarbonate	5.85
Iron bicarbonate	.97
Calcium sulphate	75.15
Sodium chloride	12.73
Potassium chloride	9.60
Calcium chloride	6.10
Magnesium chloride	41.86
Alumina	.41
Silica	.52
Organic matter	.67
Total	167.20

The water has a considerable resemblance to that of Bath, England. It contains, however, a much larger proportion of chloride of magnesium.

James K. Crook

BUTYL CHLORAL HYDRATE.—$C_4H_5Cl_3O,H_2O$. This substance, formerly erroneously styled *croton chloral hydrate*, was introduced into medicine in 1870 by Liebreich, but has not met with much favor, and has failed to secure official recognition in the United States Pharmacopœia. Butyl chloral hydrate is in the form of colorless crystalline scales, of an odor and taste reminding of ordinary chloral hydrate. It has the disadvantage, as compared with the latter substance, of being but sparingly soluble in cold water. It dissolves freely in alcohol, in glycerin, and in boiling water.

Butyl chloral hydrate is closely allied, chemically, to ordinary chloral hydrate and resembles that compound in its effects upon the animal system. Its only recommendation to medical favor lay in its supposed property of being peculiarly anodyne to the trigeminal nerve (Liebreich), and so of peculiar promise for the alleviation of neuralgias of the face and head; but this property certainly does not exist to any marked degree. Practically, the drug is only a comparatively insoluble, and therefore inconvenient, substitute for ordinary chloral hydrate. It may be given in doses ranging from 0.30 to 2.00 gm. (gr. v. to xxx.) in syrupy mixture.

Edward Curtis.

BYRON SPRINGS.—Contra Costa County, California. Post-Office.—Byron Springs. Hotel and cottages. These excellent springs are pleasantly situated near the foot-hills, on a spur of the Coast Range of mountains, about 16 miles southeast of Mount Diablo, and 68 miles northeast of San Francisco. They are reached by the railroad line running from San Francisco to Stockton and Sacramento viâ Martinez. The springs are one mile and a half from Byron Station on this line. They lie in a small valley leading from the San Joaquin plains. The elevation is about 100 feet above tide water, and the climate is mild and pleasant. An excellent hotel and a number of cottages have been erected for the accommodation of guests. Being only three hours' ride from San Francisco, the place is visited by thousands of people every year, and is constantly increasing in popularity. The springs are upward of fifty in number, and many of them are of great therapeutic value. They range in temperature from 52° to 140° F. Within a few feet of each other one finds a cold carbonated spring and a hot sulphureted spring. The entire basin has the appearance of being an extinct volcanic crater. The cold soda springs probably come largely from the surface water, while the hot springs undoubtedly have a much deeper origin down in the earth's crust. Of the fifty or more springs only seven or eight are in active use. We present several analyses made by Dr. Winslow Anderson:

The "Liver and Kidney" Springs.

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	622.07
Potassium chloride	33.74
Potassium iodide	.79
Potassium bromide	Trace.
Magnesium chloride	3.92
Magnesium carbonate	15.75
Calcium chloride	85.37
Calcium sulphate	1.12
Calcium carbonate	.59
Barium carbonate	.93
Ferrous carbonate	.72
Ammonium chloride	.05
Silica	1.00
Organic matter	Trace.
Total	766.05
Free carbonic acid gas	7.82 cubic inches.
Temperature of water	66° F.

The analysis shows this water to be heavily impregnated with saline ingredients. The water is said to have a special action on the liver and kidneys, which fact gives the spring its name. It is said to be very useful in dyspepsia, chronic hepatic diseases, obstruction in the gall ducts, and what is known as "gin livers." Its good effects are also observed in intestinal atony or torpidity of the bowels. The water is diuretic, and is said to have been successful in a number of cases of albuminuria. Its best effects are observed in alcoholic dyspepsia, and in the "rocky" and dilapidated state of the system consequent upon excessive conviviality.

The "White Sulphur Spring."

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	12.01
Sodium bicarbonate	12.94
Sodium sulphate	1.34
Potassium chloride	Trace.
Potassium carbonate	2.37
Potassium sulphate	Trace.
Magnesium chloride	"
Magnesium carbonate	2.50
Calcium carbonate	1.13
Calcium sulphate	.51
Ferrous carbonate	3.00
Silica	.26
Organic matter	Trace.
Total	36.06
Carbonic acid gas	21.17 cubic inches.
Sulphureted hydrogen	5.80 "
Temperature of water	76° F.

This will be seen to be a light alkaline-sulphur water, with a well-marked quantity of ferruginous salt. Its action is tonic, diuretic, alterative, aperient, and antacid. It is very useful in affections consequent upon the uric-acid diathesis, such as rheumatism, gout, glandular enlargements, and many forms of skin disease.

The "Black Sulphur Spring."

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	395.00
Sodium sulphate	Trace.
Sodium bicarbonate	"
Potassium chloride	35.62
Potassium sulphate	Trace.
Potassium iodide	.74
Potassium bromide	.16
Magnesium chloride	1.00
Magnesium carbonate	9.50
Calcium chloride	9.00
Calcium sulphate	3.20
Calcium carbonate	5.95
Ferrous carbonate	.70
Barium carbonate	Trace.
Ammonium chloride	"
Silica	1.10
Organic matter	Trace.
Total	461.97
Carbonic acid gas	25.60 cubic inches.
Sulphureted hydrogen	8 "
Temperature of water	90° F.

This water contains a considerable quantity of the chlorides and carbonates, and is largely diuretic in consequence. It is also heavily charged with carbonic acid gas, and has a fair amount of sulphureted hydrogen gas. It is indicated in catarrhal irritation and inflammation of the genito-urinary tract, and has proved of service in cystitis, Bright's disease, dyspepsia, and constipation. It is largely used for bathing purposes.

Among other valuable springs at Byron are the "Iron" spring, a well-marked alkaline-chalybeate water; the "Hot Salt" spring, having a temperature of 122.3° F. and much used for bathing; the "Iron Pipe" spring, and the "Surprise" spring. This latter spring is one of the most heavily charged saline waters in the world, containing 15,000 grains of common salt to each United States gallon of 231 cubic inches. With other mineral ingredients it is known to possess over 18,000 grains—about 40 ounces, or 33 per cent. of solid constituents to the gallon. The following comparative table of heavy waters shows the Surprise spring to be one of the most remarkable known.

One United States Gallon Contains:

	Grains.
Sea water	2,138.91
Mono Lake (Cal.)	2,915.16
Castalian Mineral Spring (Cal.)	4,422.25
Owens Lake (Cal.)	7,000.60
Syracuse, N. Y. (salt well)	9,221.00
Salt Lake (Utah) about	11,000.00
Dead Sea (Holy Land)	13,488.10
St. Clair Springs (Mich.)	17,704.60
Clark's Red Cross Mineral Springs (Mich.)	17,825.77
Byron Surprise Spring	18,773.73

The water is highly diuretic and laxative when taken internally, and ought to be valuable for bathing purposes. Two large bath-houses have been built at Byron, fitted with sulphurous, steam, vapor, and water baths in tub or plunge, at all temperatures. The moor or mud baths form an important feature of this resort. The hot sulphurous, saline mud has become famous in the treatment of obstinate cases of rheumatism, gout, arthritic joints, scrofula, and skin diseases. The following analysis shows the mineral constituents of this mud:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	274.93
Sodium phosphate	42.16
Potassium chloride	26.40
Potassium iodide	.32
Potassium bromide	Trace.
Magnesium chloride	2.06
Magnesium sulphate	19.60
Calcium chloride	7.50
Calcium sulphate	36.05
Calcium carbonate	3.09
Ferrous sulphate	.76
Ammonium chloride	Trace.
Silica	5.62
Organic matter	7.34
Total	425.83

Free carbonic acid gas	17.75 cubic inches.
Free sulphureted hydrogen	14.50 "
Temperature of mud	110° F.

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Winslow Anderson: The Mineral Springs and Health Resorts of California, 1892.
J. K. Crook: The Mineral Waters of the United States, 1899.

James K. Crook.

CACAO, BUTTER OF.—*Oleum Theobromatis. Oil of Theobroma.* "*Cocoa Butter.*" "A fixed oil expressed from the seeds of *Theobroma Cacao* L. (fam. *Sterculiaceæ*)" (U. S. P.). The chocolate tree is a native of tropical South America, where we have occasionally seen small forest areas which consisted almost wholly of it. These wild trees only occasionally produce fruit, for which the trees are very extensively cultivated in all tropical countries. There is great variation in the quality of the seeds coming from different regions. Under cultivation, the tree grows like an apple tree, which it closely resembles, from a distance, in form and general appearance. The oblong-ovate leaves are about a foot in length, thick, and rich-looking. The flowers are small and inconspicuous, growing in little cymes directly from the bark of the branches, or even of the trunk. The fruit, about six to ten inches long and half as thick, is oblong-ovoid, coarsely ribbed or grooved, so as to look not unlike a narrow, pointed melon. It has a thick, hardish rind, like a pumpkin or squash, and its color varies through shades of yellow, orange, and red to purple. It is filled with a whitish pulp, as soft as the flesh of a ripe melon and of a very fine texture. The numerous seeds are embedded in this pulp and attached to a soft central placenta. This pulp forms the basis of a delicious jelly of a beautiful purple or wine color. The seeds, after being cleaned of the pulp, are known as raw seeds. In this condition they are bitter and astringent and unfit for use. Two methods of curing are in vogue. The first is to enclose them in tight boxes and allow them to "sweat." The second is to "clay" them by burying in holes in the earth. Either process results in fermentation, by which the outer coating is caused to peel off, and they lose their disagreeable taste. They are then dried, cleaned, and marketed under the name "cacao" (pronounced (kah-kah'-o; or in English, kay-kay'-o). Venezuelan clayed cacao is probably the most highly esteemed and is the most expensive. The seeds are about as large as unshelled almonds, oblong-ovoid and somewhat flattened, blunt at both ends, of some shade of brown, veiny on the outer surface. The shell is thin and brittle, the cotyledons friable and fatty. The latter are wrinkled, and in good seeds fill the cavity loosely, with an irregular, small space in the centre. The taste is slightly bitterish, but agreeable. For chocolate manufacture, the seeds are roasted and shelled and the kernels finely ground into a paste, with or (usually) without a very slight addition of water. In the process a portion of the oil separates. In the earlier manufacture in the United States, this, with frequently an additional portion, was removed, making our chocolate dry. We have since learned so well from our tropical relatives that we not only retain all of this oil, but abstract a portion in making the poorer grades of chocolate, to add to the richer and finer grades.

The seeds yield almost half their weight of fat, about a third as much albuminous matter, considerable starch, and about one and one-half per cent. of the alkaloid *theobromine.* The shells removed from the seeds yield about one per cent. of this alkaloid. They are utilized for the preparation of an inferior drink. The use of chocolate produces, in a milder degree and after a longer time, the cerebral stimulation of coffee. As the latter acts through its caffeine, which is methyl theobromine, it would appear that some transformation of the theobromine of chocolate must occur in the system.

Cacao butter is obtained from the seeds by the aid of heat, either by pressing with heated rollers or by boiling. The cake which remains is ground into "breakfast cocoa." The cacao butter occurs in cakes of a yellowish-white color; has a slight, agreeable odor and an oily taste, a little like that of chocolate. Its specific gravity is from 0.970 to 0.980. It melts at from 86° to 91.4° F., and is soluble in 100 parts of alcohol. It is much subject to adulteration with other fats, for the detection of which the Pharmacopœia provides ample tests. The peculiarities of this fat are its hardness and its melting point, at about the temperature of the body. This combination renders it exceptionally useful for the making of suppositories and bougies. As it does not readily decompose like other fats, it becomes a useful base for medicaments, and is, for the same reason, frequently employed in hot countries as a delicious substitute for butter. It has no distinctly medicinal action.

Henry H. Rusby.

CACHEXIA.—GENERAL PATHOLOGY.—DEFINITION.—The term as now used designates a condition of marked anæmia associated with great emaciation. The causes of the condition are many. Formerly the term was used rather loosely to designate any state of deterioration of the general health. This led to its use as a generic term, while numerous specific terms designated the causes in individual cases; thus, C. canceratica, C. cardiaca, etc.

ETIOLOGY.—Cachexia is not associated with the primary anæmias, namely, pernicious anæmia, chlorosis, leukæmia, and pseudo-leukæmia. In these the general bulk of the frame is well maintained, and in some cases may be increased. In the secondary anæmias the associated emaciation in grave cases leads to the typical picture of cachexia.

The term cachexia, however, is especially used in connection with certain diseases. The most generally recognized types occur in malaria, syphilis, lead poisoning, gastric carcinoma, and infantile scurvy. It is well, however, to consider all the pathological processes which may lead to this state. The condition resulting from the removal of the thyroid gland, sometimes spoken of as cachexia strumipriva, is a special condition not to be considered under the general subject of cachexia.

In this connection the work of Lazarus * on the secondary anæmias has been largely drawn from; his etiological classification is especially valuable. He divides the secondary anæmias into three classes: (1) *hypoplastic,* due to insufficient blood formation; (2) *consumptive,* caused by abnormally extensive destruction of the blood; and (3) *complex,* resulting from a combination of these two causes. Of the consumptive anæmias the post-hæmorrhagic is the purest type. In most cases the pathological processes are so complex that it is impossible to determine whether the hypoplastic or the consumptive factor obtains. The examination of the blood gives no clew to the cause, as the hæmatology of most of the secondary anæmias is practically the same.

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* Ehrlich-Lazarus: "Die Anaemie," II. Abtheilung, 1900.

Krehl* says that the hypoplastic anæmias are due to an injury of some organ concerned in the production of a constituent of the blood. It is certain that many organs are concerned, and a disturbance of any one of these may bring about the result.

The consumptive anæmias may involve the destruction of normally produced blood. Here, also, many organs are probably concerned. The production of substances necessary for the preservation of the erythrocytes in the plasma might be limited, or deleterious substances might be produced. As another possibility might be mentioned acceleration of the normal destruction, by whatever processes that is brought about.

An evidence of increased destruction within the body is an increase in the amount of iron in the liver, spleen, and bone marrow. When the anæmia is due to loss of blood, the amount of this iron is decreased as a result of the activity of the regenerative processes.

The causes of the secondary anæmias may be classified as follows:

I. Hæmorrhages.

II. Insufficient nourishment and bad hygienic surroundings.

III. Malignant tumors and other organic diseases, poisons, parasites, etc.

I. *Hæmorrhages.*—The loss of blood may occur from: (1) the nose; (2) the lungs; (3) the gastro-intestinal tract in association with ankylostoma duodenale, ulcus ventriculi et duodeni, malignant tumors, and hemorrhoids; (4) the genital tract in women; (5) the bladder; and (6) it may also occur in the various forms of hæmorrhagic diathesis. Considerable losses are compensated for if sufficient intervals occur between the hæmorrhages. The more frequent the hæmorrhages the longer is the time required for this compensation.

II. *Insufficient Nourishment and Bad Hygienic Conditions.*—No satisfactory explanation of the anæmia is given. Improper food and surroundings (light, air), hard work, and mental distress are ordinarily given as the causes. Experiments upon professional fasters and upon animals have shown that acute and complete starvation does not produce anæmia. In the more chronic cases, however, it occurs especially when the diet is poor in iron-containing foods, of which the most important is meat. As these are the most expensive foods, this is probably an important factor among the poorer classes. In infantile scurvy the cachexia associated with the subperiosteal extravasation of blood is usually a result of improper feeding. Malted milk and condensed milk are most largely responsible. Animal experimentation and the experience of members of polar expeditions in the long polar nights seem to show that lack of light does not produce anæmia or have any other bad effects. Concerning the ill effects of polluted air, little is known.

III *Malignant Tumors and Other Organic Diseases, Poisons, Parasites, etc.*—There is hardly an important pathological condition that does not have its effect upon the blood and upon the bulk of the frame. The reduction in the amount of food in disease of course aids in producing anæmia and emaciation.

In *suppurations* there is a loss of important materials and a considerable additional expenditure of energy. The great draft upon the bone marrow is shown experimentally by the increase of the red marrow, and by the relative increase of the neutrophiles — especially the mononuclear forms—and the relative decrease of the eosinophiles.

In *spermatorrhœa, lactorrhœa, catarrh of the air passages and of the alimentary tract,* the same causes obtain.

In *albuminuria* the loss of albumin probably brings about a state of hydræmia, and this latter condition no doubt exerts a deleterious effect upon the red blood corpuscles. The associated intoxication is also probably a factor.

In *fevers* the amount of hydrobilirubin in the urine is to a certain extent a measure of the destruction of the red blood corpuscles. Experimentally the simple elevation of temperature probably does not increase metabolism extensively, or alter the quality of the blood. Practically, however, the associated intoxication, as in the infectious diseases, is probably the important factor. The toxins may exert an erythrocytolytic function

Diseases of the Digestive Tract. These are among the most frequent causes. Limitation of alimentation and intoxication operate as factors here. Decreased excretion of toxins, and possibly auto-intoxication, occur.

In *syphilis* the anæmia and emaciation are probably due to the specific toxin of the disease.

Tumors. Uncomplicated benign tumors have no effect upon the general health. Uncomplicated malignant tumors produce marked anæmia and emaciation. The cause is to be sought in a toxin which increases blood destruction and proteid metabolism.

Animal Parasites. Most of these probably produce toxins. The eosinophilia which occurs in connection with most, if not all, of the intestinal parasites is to be regarded as evidence of this. This is true of oxyuris vermicularis. In the case of ascaris lumbricoides the mechanical irritation may be a factor. With the echinococcus and the trichina no anæmia occurs. The complications seem to be responsible for the anæmia in the case of filaria sanguinis hominis and distoma hæmatobium. In ankylostoma duodenale the blood removed by the worm is an important factor. In the urine of patients infected with this worm is a toxin which produces marked anæmia in rabbits. In malaria a toxin undoubtedly exerts an influence in addition to the direct destruction of the erythrocytes by the parasites.

Poisons. In lead poisoning the anæmia is thought to be due to the lesions of the stomach and intestines. Arsenic probably destroys the erythrocytes directly.

In any of the above conditions, if there be marked emaciation, the condition of cachexia may be brought about.

PATHOLOGICAL ANATOMY AND HISTOLOGY.—*Blood.*—The condition of the blood is that of a secondary anæmia. In only a few forms is a special feature noted; as, for instance, the presence of parasites in the case of malaria.

Other Organs.—The skin is yellowish rather than white, as in the acute anæmias. This is to be regarded as an expression of the increased destruction of the erythrocytes. The tendency to œdema and hæmorrhages is probably due to changes (fatty) in the blood-vessels. Hæmorrhages may occur into the skin, the mucous membranes, the central nervous system, and the serous membranes. No characteristic changes in metabolism are known. It is often impossible to say whether the gastro-intestinal disturbances which so frequently occur are primary or secondary.

Certain lesions sometimes spoken of as characteristic of pernicious anæmia may also occur in these grave secondary anæmias. Such are hæmorrhages into the omentum, fatty degeneration of the heart, degenerations in the brain and spinal cord, and atrophy of the mucous membrane of the gastro-intestinal tract. Changes in the bone marrow consist of an increase of the red marrow. This may gradually encroach upon the territory of the yellow marrow in the shafts of the long bones. However, the hyperplastic marrow has normal histological characters.

In the emaciation the most important tissues suffer least. The greatest reduction is of the fat; then follow the muscles, skin, liver, bones, heart, and central nervous system. The organs show no striking histological alteration. The atrophy of the fatty tissues is described as follows by Ribbert.* In cases of marked cachexia the fat, especially of the epicardium, may assume an œdematous, gelatinous character. In frozen sections of the fresh tissue one sees, in place of the large, closely packed fat cells, groups of fat droplets in a clear vascular tissue. Under a high power these groups are seen to be contained within cells which represent the atrophied fat cells. If the process is still more advanced they take on the character of the ordinary connective-tissue cells. Between these are connective-tissue fibres.

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* Krehl: "Pathologische Physiologie," Leipzig, 1898, S. 125.

* Ribbert: "Lehrbuch der pathologischen Histologie," Bonn, 1896, S. 11.

H. S. Steensland.

CACHEXIA STRUMIPRIVA. See *Thyroid Gland, Diseases of.*

CACTACEÆ.—(The Cactus family.) This strange and interesting family of plants occupies as yet a most uncertain place in the materia medica. It comprises some twenty genera and probably six hundred species, and its study is no less difficult for the botanist than for the pharmacologist. The plants grow chiefly in desert regions, being competent to withstand the most extreme conditions of aridity, and interest centres chiefly in their defensive provisions. The absence of leaves, which are usually metamorphosed into spines, protects them against desiccation. The succulent nature of their stems causes them to be sought by hungry and thirsty animals. In times of cattle famine, the spines are burned off and the stems then used as fodder, while a wholesome water supply can be obtained from cavities scooped out in the bodies of some of the thicker species. Against destruction from such causes, most of them are protected by their armament of spines. Those which lack this armature are commonly protected by poisonous alkaloids, and attempts have been made to utilize some of these in medicine. The important drugs of the family are the *Cactus grandiflorus* and the *Mezcal Buttons*, which see.

Their physiological properties are diversified. The berry-like fruits are commonly edible, and some of them, like the Prickly Pear or Tunya, are of much economic importance. Several of them are hosts for the valuable cochineal insect. Many succulent plants not related to this family are popularly called cactuses.

Henry H. Rusby.

CACTUS GRANDIFLORUS.—CEREUS GRANDIFLORUS. The flowers of *Cereus grandiflorus* (L.) Miller (fam. *Cactaceæ*). The stems have also been used. This plant, the well-known Night-Blooming Cereus of cultivation, is a native of the West Indies, and flowers in August. Adulteration with, or substitution by, the flowers of *Opuntia decumana* Haw. is very extensive. The flowers of the latter are cup-shaped, about an inch long and broad, with stamens one-fourth or one-half of an inch in length; while the genuine flowers are eight to ten inches in diameter when fully spread out, and have stamens two or more inches long. Much of the contradictory testimony as to composition and properties is doubtless due to this irregularity in the drug used, yet there is a wide discrepancy of opinion as to the merits of that which is genuine. No efforts appear to have been made to compare the flowers collected in different stages of maturity. The facts here stated, however, appear to be fairly well established. Both the stems and the flowers appear to be active, but the latter more so. An alkaloid and a glucoside are claimed, but our information regarding them is very meagre and indefinite. The drug is a cardiac stimulant of peculiar action. It does not affect the stomach nor the centres as digitalis does. It increases blood pressure by quickening and strengthening the heart beat, through direct action upon its nerves. Wilcox, who has studied it extensively, is positive in asserting its value in aortic regurgitation, where digitalis cannot be used, but its injuriousness in mitral stenosis. He recommends it generally in relative cardiac incompetency and functional cardiac weakness. The dose of the fluid extract is 0.6 to 2 c.c. (♏x. to xxx.).

Henry H. Rusby.

CADAVER, LEGAL STATUS OF.—*Scope of the Subject.*—The enactments of State legislatures and the regulations of sanitary codes in regard to the cadaver constitute the purely legal side of the subject, and are too extensive to be considered in detail. So far as they affect physicians, as practitioners, investigators, instructors, and medical examiners, they fall within the scope of an article suitable for this HANDBOOK.

Questions involving the cause of death, and such other deductions as only a person possessing expert anatomical, medical, and surgical knowledge would be able to make from an examination of the cadaver, constitute the medico-legal side of the subject. Those matters, which can be determined only by an autopsy, have been considered in Vol. I under *Autopsies, Medico-Legal Relations of.* Besides pathological conditions, the cadaver presents certain appearances which form a basis for the determination of the fact of death, of the time when it occurred, and of the identity of the dead person.

Legal Aspects.—If we consider the subject from the physician's standpoint, it will be sufficient for us to enumerate the latter's duties and privileges in relation to the cadaver; we shall scarcely be expected to specify in detail the statutes and codes that relate to the subject. For more detailed information in regard to the latter the reader is referred to an excellent article by T. C. Becker on the "Legal Status of the Dead Body," in Witthaus and Becker's "Medical Jurisprudence, Forensic Medicine, and Toxicology."

A death having occurred in a physician's practice, it is his duty to examine the cadaver and verify the occurrence by unmistakable signs presented. (These will be discussed further on.) No statute or code requires this in so many words, but the physician's "Certificate of Death" presupposes such examination to have been made.

The "Certificate of Death" is a record and legal proof of death. The form is furnished by the health authorities, and on its reverse side it contains terse information about the legal requirements. The extent to which these are either neglected or disregarded in New York, and presumably elsewhere, is remarkable. Such neglect is frequently responsible for many vexatious occurrences that might and should be avoided.

The attending physician must furnish such a certificate within a specified time (thirty-six hours, according to the New York Sanitary Code, sec. 180).

The physician must be officially registered (New York Sanitary Code, sec. 5.; Bureau of Records).

The cause of death must be sufficient, no mere symptom being given as the sole cause.

When a cause of death is given which might possibly be the result of injury, if such is not the case the certificate should make that fact plain.

If death is due to other than natural causes, the case must be referred to the coroner, county physician, medical examiner, or justice of the peace, according to the law of the State. In doubtful cases the practitioner should not furnish the certificate unless authorized to do so by the proper official. Such cases are specified by statute in the various States. That of New York State is very broad. If a person dies from criminal violence, or by a casualty, or suddenly while in apparent health, or when unattended by a physician, or in prison, or in any suspicious or unusual manner, the case must be referred to the coroner's office (chap. 410, sec. 1,773, laws of 1882).

Still-Birth.—The still-born fœtus or child at full term is certainly a dead human body, having been alive in utero; yet the law takes no cognizance of this fact, and does not require an inquiry into the cause of death, unless it can be proved that the child was born alive and capable of maintaining a separate existence; the decision of the former fact being based upon breathing; of the latter, upon normal formation and sufficient development.

The physician or midwife in attendance at a still-birth should make a report thereof to the proper authorities. In New York, certificates are furnished by the Bureau of Vital Statistics, and these certificates require, besides other information, a statement of the "cause of death-birth, if known."

Concealing the birth of a child, which if born alive would be a bastard, is punishable in seventeen States.

A failure on the part of the physican to make a proper return to the authorities in a case of this nature might be construed as such concealment.

Autopsies.—In cases in which the coroner, county physician, medical examiner, or justice of the peace has jurisdiction, an autopsy may be ordered or performed by him (county physician, medical examiner, coroner's physician) to ascertain the cause of death. If the body has been interred, the coroner, justice of the peace, or district attorney—this duty falling upon a different officer in different States—may exhume, take possession of, and remove the body or any portion thereof, and submit the same to a proper physical or chemical examination or analysis to ascertain the cause of death, which in New York "will be made on the order of a justice of the supreme court of the State, or the county judge of the county in which the dead body shall be, granted on the application of the district attorney," etc. (sec. 308, Penal Code, subdiv. 3, as amended by chap. 500, laws of 1889). When the officials mentioned have no jurisdiction, an autopsy may be authorized by husband, wife, or next of kin. If no relatives charged by law with the duty of burial are at hand, and the deceased has left a will, his executors may authorize the performance of an autopsy. If the body has been interred, it may be exhumed on such authorization with the permission of the health authorities.

The removal or disinterment of a dead body without authority of law, or consent of relatives, for the purpose of selling such body, or for dissection, or for mere wantonness, is a felony, misdemeanor, and punishable by sentences which vary in different States.

The time that should be allowed to elapse before performing an autopsy is not specified by statute. It is best to await the development of unmistakable signs of death, the time for which varies in different cases and under different circumstances. This matter is discussed further on.

Dissection of bodies unclaimed by relatives or friends for burial is permitted by various State enactments. Their phraseology varies. In general, they are worded so as to include the bodies of criminals executed under sentence, those of persons dying in jails, poorhouses, asylums, and public hospitals, and those lying in undertakers' establishments—in brief, bodies which would otherwise be buried at the public expense. Dissection is prohibited in some States, under the following circumstances: if the deceased in his last illness expressed the wish that his body should not be used for such a purpose; if relatives or friends withhold their consent; if deceased was a stranger or a traveller; or, finally (in Maine), if ten voters object.

The Powers and Duties of Coroners, County Physicians, Medical Examiners, and Justices of the Peace in relation to the disposition to be made of a cadaver. A consideration of the coroner's inquest, and of the systems which have superseded it, although related to this subject, would occupy more space than can be spared in the present article.* In those cases in which these officials have jurisdiction, no disposal may be made of the body without their sanction. No person, however, would be adjudged as infringing such authority if he were immediately to cut down a suspended body on the chance of life not being extinct, or if he should in some other manner lay hold of the body in efforts at restoration.

The wisdom of having an official who is duly authorized, in a suspicious case, to take possession of the cadaver, of its effects, and even of the quarters in which it is found, while at the same time all other unauthorized persons are prohibited from disturbing the body, its effects, or the quarters in which it is found before such official possession is taken, is apparent, when the great importance of a proper record of all details in relation to the cadaver and its surroundings as first discovered is considered. Circumstances which seem at the time to be trivial may prove of prime importance at the trial. Expert medical knowledge is very useful in the first examination of the cadaver, especially in relation to the position which it occupies in the midst of surrounding objects; to the disposition of any blood and stains that may be present; to rigor mortis, and to other signs upon which the time that has elapsed since death took place may be estimated. Evidence furnished by one who possesses such knowledge is more to be depended upon than that given by a layman, and the results of the earlier examination are naturally more valuable than those secured after the cadaver or surrounding objects have been disturbed.

Determination of Death.—Immediate continuance of life depends upon respiration, circulation, and innervation. Cessation of any one of these functions entails that of the others. Clinically death is determined by complete arrest of both respiratory movements and heart's action, on examination with the stethoscope. Electro-muscular irritability may still continue for a variable length of time, not longer than six hours thereafter. Reaction of the pupil to light, and spasmodic movements of facial muscles, have been noted in cases of decapitation. The pupil may react to atropine for as long a time as four hours, and to eserin for two hours, post mortem. Respiratory movements and heart's action do not necessarily cease together. Temporary absence of respiration is not incompatible with the continuance of life. In the new-born, cases are on record in which respiration was not established until one and even two hours after birth. The heart's action may be extremely feeble in such cases, even inappreciable by the stethoscope. It cannot be doubted that respiratory movements may be so shallow, and the heart's action so slow and feeble, that both may be inappreciable, though not necessarily arrested. The usual clinical determination of death, although correct in the vast majority of cases, must therefore be considered as entirely inadequate. No grave error is probable, however, provided the conditions be kept in mind under which the state of apparent death, or one resembling it in some of its phases, is produced.

Apparent Death; Lethargy; Catalepsy.—Many stories of apparent death, and of burial alive, are entirely imaginary or are based upon certain appearances observed in exhumed remains—appearances which may readily be explained as effects of the gases of decomposition. A few authentic cases are on record in which life seemed extinct, but afterward became evident again. In these instances respiratory movements and heart's action could not be appreciated, and muscular relaxation, pallor, and marked reduction of surface temperature were present. In one case electro-muscular irritability was preserved throughout the period (thirty-three hours) of apparent death. It is hardly credible that respiration and circulation were actually arrested.

Besides the condition of apnœa in the new-born, and in cases of submersion in which it is stated respiration has been established after a lapse of half an hour or even longer, the conditions of lethargy and catalepsy might be mistaken for death by the laity, and occasionally by a physician, if reliance were placed upon apparent arrest of respiratory movements and heart's action alone. The muscular relaxation of lethargy, with apparent arrest of respiration and circulation, reduction of temperature, and absence of reflexes, may closely resemble death. However, there are other signs presented by the cadaver, even within a few hours after death, which render the decision quite easy. The rigidity of catalepsy, although presenting some resistance to passive motion, is readily overcome, and after such motion the limb remains rigid in the position in which it is placed (flexibilitas cerea). When rigor mortis is well established the rigidity does not return after it has been overcome. Lethargy and catalepsy are phases of the hypnotic condition that occur in hysteria. Lethargy may be the last stage of one of the acute infectious diseases; it occurs also in epilepsy and in the sleeping sickness of Africa, and it may follow cerebral injuries. Catalepsy also occurs in melancholia, in progressive paralysis, in meningitis, in brain tumors, and in apoplectic coma. (For further information, see under these headings.)

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* *Vide* "The Powers and Duties of Coroners and Medical Examiners," by August Becker, in Witthaus and Becker's "Med. Jurisp., Forensic Med., and Tox.," vol. i.

Signs of Death, their Application. — After death the body presents certain appearances which are due to physical and chemical changes. The character of these appearances, their causes, the time of their inception, their duration and disappearance, are matters of considerable importance, both as signs of death and as aids in establishing the time of death. Moreover, a thorough knowledge of these cadaveric appearances and of their relations to different pathological processes is necessary if one wishes to avoid drawing unwarranted conclusions. In regard to establishing the time of death—often a very important medico-legal question—no absolute rule can be given, since the cadaveric appearances may be subject to variations due to age, sex, constitution, and environment of the cadaver, and to the cause of death (namely, previous disease, injury, or poison). Consequently, great caution is necessary in arriving at a conclusion, and all the various conditions must be taken into account. It will therefore be best to consider carefully the cadaveric appearances, or signs of death, seriatim, their usual chronology, and the variations to which they are subject; and at the same time the conclusions which one is warranted in drawing from these appearances should be pointed out.

Muscular Relaxation. After death a primary period of complete muscular relaxation precedes the onset of rigor mortis. Some observers have maintained that voluntary muscular contraction at the time of death may immediately pass into post-mortem rigidity (cataleptic rigor mortis of Du Bois-Reymond).

Reduction of Temperature. The cadaver loses heat and, by evaporation, its temperature sinks below that of the surrounding atmosphere. Exceptionally a rise of temperature occurs post mortem, as after some infectious diseases; after cholera, tetanus, and diseases of the central nervous system; after asphyxia; after poisoning (accompanied by asphyxia and convulsions), and after injuries of the brain and upper part of the spinal cord. The temperature may reach 44° C. (111.2° F.), and be maintained at this height for from fifteen to twenty minutes. On the other hand, in cases of hemorrhage, drowning, and exposure to cold, and possibly in those of burns and scalds (through a loss of epidermis), the temperature is apt to sink rapidly (Hofmann). Within from 8 to 17 hours (according to Caspar) the body becomes cold to the touch. According to Seydeler, a period of from 23 to 38 hours is required before complete cooling, as shown by the use of the thermometer, takes place. Maschka's investigations showed that in an atmosphere of from 8°–15° R. (50°–65.7° F.), adult cadavers, lying upon a board or mattress, and covered with a sheet or simply naked, became cold to the touch in from 8 to 10 hours. Only in rare instances was a period as long as from 11 to 13 hours, or one less than 8 hours, required. Cooling of the parts takes place in the following order: feet, hands, and face, in from 1 to 2 hours; then gradually the extremities, chest, back, and belly. The epigastrium, axilla, and neck on either side of the larynx are the last spots to cool. The abdominal organs may still be warm at the end of from 16 to 24 hours after death. The rate of cooling is given by Goodhart as 4° F. per hour in the first 3 hours; 3° F. per hour in the next 6 hours; thereafter, a little more than 1° F. per hour. Bowman estimates the rate to be 2° F. per hour for the first 8 hours.

Cooling is postponed for a period of from 2 to 3 hours by clothing, and for one of from 3 to 4 hours by bed covering, hay, or straw. In a case reported by Maschka the body of a person who had died from epilepsy in bed was found to be still warm after the lapse of 14 hours; and in another case, one of homicide, reported by the same author, the body, covered with horse hair, was found to be still warm after 16 hours.

Obesity may postpone complete cooling for as long a time as from 2 to 3 hours. The bodies of those who are extremely obese may have the same degree of surface temperature 12 hours after death that the ordinary cadaver presents after the lapse of 2 hours (Hofmann). In such cases one may find the internal organs, 30 hours after death, still warm, although, as a matter of course, the surface of the body will be cold.

The cadavers of the new-born and of infants become cold in from 5 to 6 hours.

In ice and snow cadavers of adults may become cold in half an hour or an hour; in cold water they become so in from an hour and a half to two hours. After the human body has been in water at 18° R. (72.5° F.) for from ten to twenty minutes the surface may already be cold, and yet the epigastrium, the axillæ, and the neck on either side of the larynx are likely still to manifest some warmth (Maschka).

With progressive putrefaction a rise of temperature has been noted (Mende).

Evaporation produces changes in the eye, skin, mucosa of the lips, and hair.

Eye.—The globe loses its normal tension, becoming flaccid and softer. This is partly due to post-mortem sinking of blood, when the head rests in the usual position upon the occiput. The cornea loses its transparency, and is thrown into folds by the loss of intra-ocular tension. The earliest period in which these changes become apparent is from 2 to 3 hours after death. The transparency of the cornea may be retained for from 10 to 12 hours, or even, in some cases, for from 24 to 30 hours (Caspar-Liman). The protection afforded by closed eyelids favors transparency, exposure favors opacity. The cornea becomes opaque earlier in children than in adults. All influences favoring putrefaction, as septicæmia, pyæmia, and an abnormally high temperature of the atmosphere, tend to hasten the occurrence of these changes. The average length of time required for the development of distinct flaccidity is from 5 to 6 hours; and by this time slight opacity of the cornea also usually develops. The triangular spots described by Larcher, with base at the corneal margin and apex toward the external canthus, of a yellowish, bluish, or even black color, are not always present. They may occur from 3 to 5 hours post mortem, may also be present between the cornea and the internal canthus, and are due to drying of the conjunctiva and sclera—a change which allows the color of the choroidal pigment to become more and more apparent.

Skin.—Wherever denuded of epidermis—whether this occurred before or after death, it makes no difference—the corium, under the favoring influence of evaporation, becomes dry, firm, of the consistence of parchment or leather, and light yellowish brown. At a still later time the color grows darker, and may even become black. Such changes may be apparent in the course of 2 or 3 hours. In fat subjects the cutaneous fold about the neck may be the seat of excoriation from eczema intertrigo. From the above changes in drying post mortem, an appearance may be produced which simulates the marks left by a constricting band. Such a condition has led to the mistaken report of strangulation. An incision will readily show that the change is confined to the corium, there being no evidence of subcutaneous laceration of tissue, of hemorrhage, or of ecchymosis.

Lips.—The mucous surface of the lips may be divided into two regions: the narrow vermillion border which is adjacent to the skin and is smoother and more intimately adherent to the underlying tissues; and the remaining larger portion, which is thrown into folds, owing to the fact that it is more loosely attached to the submucous connective tissue. The latter portion, more especially of the upper lip, may become quite dry and black as a mere post-mortem change, the condition occurring more frequently in children than in adults. The line of demarcation between this dry and black portion and the vermillion border is under these circumstances quite straight and distinct. Such a change may occur as early as 2 to 3 hours after death. It has been mistaken for the escharotic effects of acids.

The hair may become loosened and fall out or be easily pulled out, after evaporation of fluid from the hair follicle.

Post-Mortem Hypostasis.—With the cessation of the circulation the skin loses its pink tint and becomes intensely pale. In cases of cyanosis (*e.g.*, in asphyxia, pulmonary œdema, heart lesions, and alcoholism) a bluish tint may be apparent, especially in the skin of the face and neck. In cases of carbon monoxide poisoning, and in those in which death follows exposure to a low temperature, the pink tint of the skin may not only be retained but even be exaggerated. The pallor of those portions of the cadaver which lie uppermost becomes intensified by contrast with those into the veins and capillaries of which the major portion of the blood flows by gravitation. The position of the cadaver will therefore determine which are the parts that are likely to show this condition of hypostatic congestion. When the blood has thus collected in sufficient amount, spots, streaks, and patches appear in the skin of the dependent portions. At first they are small, separate, and light red or purple in color, but later they become larger, confluent, and dark red, blue, or even black in tint. At first, while the blood remains in the vessels, the color may be made to disappear by pressure. Wherever, therefore, the skin is subjected to pressure, such spots of color are absent. If the cadaver has been lying upon the back on a flat surface, pale areas occur over the bony prominences of the scapula, the dorsal spines, the buttocks, and the calf of the leg. At a later period, with the first onset of decomposition, the serum takes up blood-coloring matter and transudes through the vessel walls, staining the surrounding tissues. Such spots, then, cannot be removed by pressure.

Post-mortem hypostasis also occurs in internal organs wherever the physical conditions are favorable, namely, in the pia mater of the posterior portion of the brain and cord, posterior portions of the lungs, stomach, and intestinal wall, bladder, uterus, and adnexa, when the body has been lying upon the back. The kidney, spleen, and liver do not present conditions equally favorable for the occurrence of such hypostatic congestion. Post-mortem transudation of serum into the meshes of the pia-arachnoid, and into the pericardial, pleural, and peritoneal sacs may occur. Such conditions are frequently mistaken for congestion and inflammation, and should not alone be relied upon in making such a diagnosis.

External Hypostasis, or Post-Mortem Spots.—With a knowledge, therefore, of the manner in which these spots develop, one can readily appreciate that the total amount of blood in the body and the degree of its fluidity will exert an appreciable influence upon the time when the external hypostases will manifest themselves, upon the intensity of their color, and upon the extent of their distribution. They appear earlier, are more widely distributed, and are more intense in color in plethoric than in anæmic individuals; in those who die suddenly rather than in those who succumb to some exhausting disease or in whom the lethal agony has been prolonged; and, finally, in those who die from asphyxia, from sepsis, or from some form of poisoning in which the blood remains fluid, rather than in those who die from cholera, from tetanus, or from poisoning by arsenic or by strychnine, in both of which conditions the blood is less fluid. External hypostases usually appear from 3 to 4 hours after death, and after the expiration of from 12 to 14 hours they become widespread. Exceptionally, they may be plainly developed in an hour and a half, but usually a period of from 4 to 6 hours intervenes before they can readily be distinguished. In some instances they are not well marked and extensive until after the lapse of from 16 to 18 hours. A high temperature, or the artificial warmth afforded by coverings (clothing, bedding, etc.), causes their earlier appearance and more extensive distribution.

The color of the spots is affected by age, it being usually lighter in the new-born and in infants; it is also affected by poisons, being light red or pink in poisoning by carbon monoxide and by hydrocyanic acid and compounds, and grayish in poisoning by potassium chlorate. The light-red tint observed when the cadaver has been exposed to cold (as in water, snow, or ice) is ascribed by Hofmann to the easier access of oxygen to the blood through the moist epidermis, by Blumenstock to the interference of low temperature with the reducing power of the tissues post mortem.

After excessive hemorrhage, hypostases are late in their development and are much less marked, although rarely absent. Devergie and Hofmann have observed a few instances of such entire absence, especially in young subjects.

The presence of external hypostases is an important and reliable sign of death, and, in addition, of the position in which the body lay when they developed. The important fact should also be stated that in an early stage these areas of hypostatic congestion may disappear on changing the position of the cadaver, and subsequently appear in new places, namely, in the most dependent portions in the new position. Tourdes ascertained the following facts: that, on reversing the position of the cadaver, 4 hours after death, the hypostases which had already developed, disappeared entirely, and new ones appeared in the new dependent portions; that, at the end of from 12 to 15 hours after death, the hypostases which had developed no longer disappear, but simply grow fainter, and new ones appear; and, finally, that 30 hours after death these spots grow paler but do not appear in new dependent parts on changing the position of the cadaver. Other experiments have shown that, on changing the position of the cadaver 4, 6, and even 12 hours after death the hypostases already developed may disappear, but that this does not occur after the lapse of so long a period as from 23 to 28 hours.

Rigor Mortis. — After death muscle tissue becomes firmer and more resistant to compression and extension. Rigidity of the entire muscular system results. This rigidity offers a greater or less resistance to the movement of parts, but the resistance may readily be overcome by force. After muscle has been thus stretched, there is free mobility, and the rigidity does not return. Various theories in regard to the causation of this rigidity have been advanced. The discussion of these would be too lengthy for the scope of this article. The most plausible one ascribes the occurrence of rigor mortis to coagulation of myosin.

The time of the inception of rigor mortis, its intensity and duration, and the conditions affecting them, have an important bearing on the subject now under discussion, since rigor mortis affords reliable evidence of death, and also aids in establishing the time when it occurred. Rigor mortis does not affect all muscles equally at the same time. The determination of its presence and the estimation of its intensity and duration rest upon the degree of force necessary to overcome it, *i.e.*, in the case of the voluntary muscles, to produce free motion in the joint or joints with which the given muscle or group of muscles is related. If this degree of force were measured in foot-pounds, there might be more unanimity in the reports of different observers. As it is, the personal element, which plays a part in the estimation of this force, accounts for the more or less considerable variations. Maschka reached the following conclusions from a study of over five hundred cases:

Rigor mortis occurs in all cases, no matter what may be the cause of death. It is absent only in the decomposed cadavers of still-born infants, and locally where muscle is excessively contused, lacerated, gangrenous, or the seat of purulent or phlegmonous processes of inflammation. Rigor mortis does not follow immediately upon death in any case; a shorter or longer period of complete muscular relaxation intervenes. Strychnine poisoning, tetanus, hydrophobia, and hemorrhage cause no exception in this regard.

Rigor mortis usually begins between 2 and 3 hours after death. All the muscles are not affected at the same time. The usual order in which the rigor shows itself in the different parts of the body is the following: lower jaw, neck, trunk, and upper extremities, in which parts rigor mortis becomes distinct after the lapse of from 3½ to 4½ hours after death; then the lower extremities become affected, so that after the lapse of from 6 to 9 hours from the time of death the entire body will have become rigid. Exceptionally this order varies as follows: lower jaw, upper extremities, neck, trunk, etc.; or the lower extremities are affected before the upper; or the upper extremity of one side becomes rigid and then that of the other side, etc.

The earlier or later inception of rigor mortis is not constantly or characteristically affected by the degree of muscular development, the sex, the age, poisoning, hemorrhage, sudden death, or, with few exceptions, by pathological processes. General hydrops or œdema of an extremity delays the development of rigor in that extremity until from 4 to 6 hours after death. Paralyzed muscles may not show rigidity for 4 or 5 hours after it has appeared in the non-paralyzed muscles, although this is not always the case. In amputation stumps rigidity is developed later than in other muscles. In very atrophic or fatty muscles rigidity may be entirely absent. After acute diseases of the brain and spinal cord the rigor appears earlier. No difference in time of onset is ascribed to injuries of the brain and spinal cord which are followed by sudden death.

The covering of the cadaver, as with clothing, bedding, etc., seems to favor the earlier appearance of rigor mortis.

As regards the time of appearance of rigor mortis, there are considerable variations for which no explanation can be given. Maschka reports a number of such cases, in which the conditions, so far as they were observed, were apparently the same. In one of these cases, that of an emaciated tuberculous woman, rigor mortis began in three-quarters of an hour after death; in another, in 3 hours; in 4 cases of strychnine poisoning the facts were as follows: in a child of seven years, it began in half an hour; in 2 other cases, also children, and in a male adult, it began at the end of 1¾ hours and 2 hours respectively. Rigor mortis begins usually not earlier than one-half hour, nor later than 6 hours after death.

In regard to the intensity of the rigidity, Maschka was unable to find any constant or important difference for the production of which special influences could be held responsible.

If the cadaver is not interfered with, rigidity usually remains marked, in adults, until after the lapse of from 50 to 60 hours, and then it gradually disappears, so that nothing remains of the rigidity after the lapse of from 70 to 75 hours. In exceptional cases it may last for as long a time as 80 or even 90 hours, and then again it may disappear as early as at the end of 40, 30, or even 20 hours without special causes therefor being apparent. It is evident, therefore, that absolute rules in regard to the duration of rigor mortis cannot be laid down; for under the same development, mode of death, previous pathological processes, and external circumstances, great differences in duration have been noted.

Rigor mortis may still be present when the early signs of decomposition—such as green color of the skin of the abdomen, the sides of thorax, the neck, and the back —appear. When the cadaver swells with post-mortem emphysema, and the epidermis becomes loosened and easily strips off, rigidity will always be found to have disappeared.

In children rigor mortis usually commences at the same time as in adults. In the new-born, however, and in infants a few days old, it may appear as soon as ten minutes after death or not until after the lapse of 1½ or 2 hours. The degree of rigidity is apparently less, on account of the small muscular development. The duration is also shorter in the new-born—say from 8 to 10 hours,—yet in some cases it may last for from 36 to 42 hours, or even—in the case of infants—50 hours. In older children, when poorly nourished, the rigidity may last only for from 20 to 24 hours, but in the majority of cases it persists for 40 or 45 hours, and in some cases even for 60 or 70 hours.

Rigor mortis disappears in the different parts of the body in the same order in which it begins, the foot being the last part to become freely movable. Yet it is not unusual for the rigidity in the jaw and neck to outlast that of the extremities (Hofmann). The latter authority places the time of inception of rigor mortis at from 2 to 4 hours after death, and that of complete development at from 4 to 6 hours after inception; for the new-born and infants, he names earlier periods. According to him, the rigidity lasts for from 24 to 36 hours in the new-born, and for 40 hours in infants; in adults it is marked for 48 hours, then gradually disappears, and is absent after the lapse of from 72 to 84 hours after death. Rigidity makes its appearance earlier after hemorrhage, injury to the cervical portion of the cord, poisoning by acids and strychnine, and perhaps in insolation and lightning stroke; it either appears later or is entirely absent in acute parenchymatous degeneration of muscle (as in poisoning by phosphorus and by toadstools) and also after sepsis.

Du Bois-Reymond, Rossbach, and Brinton record instances in which rigor mortis developed immediately after death. From observations upon the battlefield, the conclusion has been drawn that rigor mortis may set in with the occurrence of death, and thus the facial expression and action which existed at the moment when death occurred may be preserved. If this conclusion were well founded, it might afford important aid in determining whether death, in a given case, were due to an accidental or inflicted injury, or to suicide. Casper-Liman, Hofmann, and Maschka point out the danger of relying upon such evidence, as the positions observed, indicating action, may simply have been the result of the passive interference of surrounding objects. They assert that, so far as their experience goes, complete muscular relaxation precedes rigor mortis. This is evident from the expressionless countenance of the dead in the great majority of cases. Occasionally such a countenance does present an expression of mirth, sadness, pain, or anger, but to draw any conclusion therefrom would be hazardous, since it may simply be due to pressure after death and before rigor mortis has set in, or it may be the result of sagging of the lower jaws and of open eyelids. In no case of death from apoplexy, so far as the writer's experience goes, can a diagnosis be made from a mere study of the facial appearance after death. On the contrary, in a case of sudden death from chronic interstitial myocarditis, without any brain lesion, the face of the cadaver presented the typical picture of hemiplegia.

In no case of suicide has either Maschka or Hofmann found the weapon grasped in the hand of the cadaver. Taylor states that he has made such an observation. Maschka's experiments in securing weapons within the grasp of one of the hands of the cadaver before rigor mortis set in, showed that they either fell out when the hands were loosened or that the grasp itself was very feeble. The writer has never encountered a case of suicide in which the weapon appeared to be grasped by the hand of the cadaver.

Decomposition of the cadaver is brought about by the invasion of saprophytic bacteria. If the conditions are such as to favor their access and growth, decomposition will begin earlier and will advance more rapidly. Access of air and moisture, and a warm temperature, in so far as they are necessary to bacterial life, favor decomposition. A cadaver exposed to the open air decomposes far more rapidly than when it is immersed under water or buried in the soil. If in a given temperature, in the open air, a cadaver requires one week or one month to reach a certain stage of decomposition, it will require, if submerged, double the length of time to reach the same stage of decomposition, or four times this period if buried under ground (Caspar-Liman). If, however, a body is exposed to a current of air, evaporation is favored, and, instead of marked or rapid decomposition, mummification may take place. Under these conditions the growth of bacteria is interfered with by the lack of water Somewhat the same conditions are established when the cadaver is buried in dry, sandy soil and at a sufficient depth. When burial is just beneath the surface, or in moist clay, decomposition is favored. The various methods of embalming all depend for their success upon the inhibition of bacterial growth by chemical means (bactericides) and, in the older methods, by the exclusion of air as well.

Freezing will postpone decomposition indefinitely, and low temperatures—above the freezing point—will prevent decomposition for a considerable length of time.

Whatever interferes with the cooling of the cadaver—as a warm, moist atmosphere, clothing, bedding, etc.—favors an earlier onset and a more rapid advance of decomposition.

The condition of the cadaver has a bearing upon decomposition. New-born and obese subjects decompose more rapidly, since fat is a poor conductor of heat. Previous pathological processes have an influence upon the condition of the cadaver and thus indirectly upon decomposition. Sudden death is followed by earlier and more rapid decomposition. Cases of asphyxia, of general œdema, of sepsis, of typhoid fever, of parturition—when death occurs during delivery or soon thereafter—and of narcotic poisoning are also more liable to undergo an early and rapid decomposition. The free use of alcohol, when death occurs during a debauch, postpones the onset of decomposition, and cadavers, after poisoning by sulphuric acid, remain fresh and odorless, while under the same external circumstances other cadavers undergo decomposition (Caspar-Liman). This statement is not confirmed by the observations of Maschka.

The bodies of individuals poisoned by carbolic acid and corrosive sublimate might be expected to decompose later and less rapidly; as a matter of fact, no pronounced effect has been noted. In the case of those dying from arsenic poisoning it has been both affirmed and denied that decomposition of the cadaver is inhibited. The weight of authority seems to be on the latter side. Although all these substances prevent decomposition when liberally applied in embalming, the amount necessary to cause death is very much less, and is not applied in the same way.

According to Tourdes, decomposition follows very rapidly upon death from lightning stroke; he found bluish spots on the integument, and gas bubbles in the liver and blood, at the end of twenty-two hours after death. On the other hand, Caspar and Liman note no unusual difference in two cases observed by them. Hot weather and exposure in the open air should be taken into account in judging the effects of this agency.

Decomposition begins in the blood. The red cells are broken up and then the serum becomes stained with blood pigment and transudes into the neighboring tissues. The external hypostases or post-mortem spots become darker and confluent, and on incision the tissue is found to be succulent and filled with stained serum. A transudation between the corium and the epidermis may lift up the latter in the form of smaller and larger blebs, or it may simply loosen it so that it is easily stripped off.

With the production of sulphureted hydrogen and the formation of sulphide of iron (blood pigment), a greenish discoloration of the integument makes its appearance: at first in the groin, then on the abdomen and sides of the thorax, and, finally, on the neck and face.

The formation of gas first in the subcutaneous areolar tissue of the face, neck, and upper part of the thorax, and later in that of the external genitals and extremities, as well as in the abdominal cavity, gives the cadaver a deformed and gigantic appearance. By pressure of the gas which accumulates from decomposition, the contents of the stomach may be forced into the œsophagus and air passages, frothy blood may appear at the nostrils and in the mouth, and the mucosa of the rectum or external genitals (in women) may be forced outward. Through a post-mortem rupture of the mucous membrane of the posterior fornix of the vagina coils of small intestine may make their appearance in the latter cavity. The fœtus has been expelled post mortem by the pressure of gas. The abdominal and thoracic walls may undergo rupture when decomposition is advanced. The eyeballs may be pressed forward, and the cranial sutures may undergo separation.

Decomposition of the organs commences earlier in parts subjected to post-mortem hypostasis, to transudation and imbibition of serum, and to easier access of air. The facility with which decomposition takes place in an organ depends in some measure upon its structure and blood supply; it occurs earlier in those organs in which the stroma is of a loose character and the blood supply abundant. Caspar and Liman give the following order as that in which the different organs undergo decomposition: mucosa of the trachea and larynx; brain of the new-born and of infants up to one year of age; stomach, intestines, spleen (sometimes earlier than intestines); omentum and mesentery; liver; adult brain; heart, lungs, kidneys, bladder, œsophagus, and pancreas; diaphragm, aorta and larger arteries, and uterus.

With advancing decomposition the organs become softer and more succulent from imbibition of transuded serum; their color becomes darker; and the markings on section grow more and more indistinct. From progressive liquefaction the tissues become mushy or pasty in consistency, and finally indistinguishable.

Microscopical examination of decomposing tissue—especially the epithelial cells of the liver and kidney and the muscle fibres of the heart—shows in the earlier stages a loss in distinctness of structure and the presence of highly refractile granules in the protoplasm; a condition upon which an erroneous diagnosis of ante-mortem parenchymatous degeneration might be made. The granules are, however, much coarser, and the nuclei, although altered, usually do not show a degenerative change apparently more advanced than that of the protoplasm. Later, the tissue becomes more indistinct and cloudy, but the parenchyma and stroma can still be made out. Finally, no structure can be identified. In decomposition of the liver, fat may find its way into the blood of the veins, and, by the pressure of the gas of decomposition, may pass into the vena cava and right heart. These facts have an important medico-legal bearing.

Since decomposition, in onset and rapidity, is influenced by so many factors, no absolute rules can be formulated for determining therefrom the time of death. We can, however, after taking all circumstances into account, state the minimum and the maximum period that must have elapsed—the former more accurately than the latter.

The following chronology of the signs of decomposition, taken from Caspar and Liman, applies to cadavers exposed to air in mean temperatures, and is subject to variation by the different influences already discussed:

Green discoloration of the groin and abdomen appears at the end of from 24 to 36 hours after death, and with it the odor of putrefaction. At this time the eyeball is soft, the cornea cloudy and wrinkled. In summer the green color may appear as early as at the end of 15 or 18 hours; in winter it may be absent even after the lapse of 4 or 5 days, when the cadaver is exposed to air. When the cadaver is submerged, this discoloration may not appear, in summer, until after the lapse of from 40 to 48 hours, and in winter it may be absent even at the end of 8 weeks (Maschka). The green color spreads in such a manner that, at the end of from 3 to 5 days, the entire abdomen and the external genitals may be involved. An irregular distribution of smaller and larger greenish spots appears upon the back, sides of thorax, neck, and lower extremities. Frothy blood may appear at the mouth and nose, especially in cases of asphyxia. At the end of from 8 to 12 days the whole body is reddish-green and darker; the spots become confluent; and on the neck, chest, and extremities, the superficial venous trunks are marked out, through imbibition, by dark red, purple, or bluish streaks. The abdomen is distended with gas. The cornea is relaxed and concave, and although very cloudy, the color of the iris may still be made out. In the fœtus the cornea is opaque. The sphincter ani is patent. The nails are still adherent. At the end of from 14 to 20 days it will be found that the discoloration is still going on. Blebs containing murky red or black serum (methæmoglobin) appear, or the skin may be denuded of epidermis in places. Post-mortem emphysema appears and increases in the subcutaneous cellular tissue of the neck, chest, and face. The penis and scrotum are increased in size thereby. The entire body presents a puffed-up appearance, and the features are so deformed that recognition is almost impossible. The cornea is opaque and the sclera of a dirty red hue from imbibition. The nails are loosened and can easily be pulled off. Maggots are present in abundance, especially at orifices and folds (as the eyelids, mouth, nose, and anus).

The rapidity with which these changes take place is markedly influenced by the surrounding temperature. At from 16° to 20° R. (68° to 77° F.) a cadaver will, in 8 or 10 days, reach a stage of decomposition that would require a period of from 20 to 30 days if the temperature were at 0° to 8° R. (32° to 50° F.).

After the lapse of from 1 to 3 or more months the greenish, putrid, and emphysematous cadavers cannot, with any degree of certainty, be distinguished from one another.

After the lapse of from 4 to 6 months—or at a still earlier period if warmth and moisture are present—putrid liquefaction of the soft parts sets in. The pressure of gas may cause rupture of the putrid abdominal and thoracic parietes, and even diastasis of the cranial bones. Entire bones, especially of the head and extremities, may be laid bare. The optic cavities may be empty. The soft parts become progressively changed into a mushy, pasty, dark mass in which their identification becomes more and more difficult, and finally impossible. Joints may be opened and loosened by beginning destruction of fasciæ and ligaments. Determination of sex by the breasts or external genitals may be impossible on account of their disappearance. The uterus, however, and probably the prostate, may still be identified, and the measurements of the pelvis will aid in determining the sex.

The entire disappearance of the soft parts, in adult cadavers, requires a period of from 2 to 3 years. Ligaments and cartilage are destroyed after the lapse of 5 years. Loss of fat from the bones and complete drying require 10 years, or even longer (Hofmann).

Adipocere.—Under certain circumstances, as exposure in water or in moist soil, without any or with only a slight access of air, the soft parts, instead of undergoing putrid liquefaction, become changed into the substance called adipocere. Recent investigations show that its formation is due to the saponification of fat. (For further information on this subject the reader is referred to the article on this topic in Vol. I.)

Identification of the Cadaver.—The strictest attention should be given to every detail, even though it may appear to be trivial, since there is a sufficient number of cases on record in which the identification made by relatives and friends in good faith, upon view of a well-preserved cadaver, has proven to be erroneous. The clothing and effects found upon the cadaver often lead to identification. They should be accurately described and preserved, yet they should not be relied upon to the exclusion of other means, since clothing and effects may be, and have been, substituted to mislead in identification. A good photograph should be taken of an unknown cadaver as early as possible and before the head has been opened. In addition, an accurate description should be recorded, embracing such data as height, weight, and build, race, sex, apparent age, shape of head and face, complexion, color of hair and iris, condition of hands and finger nails, deformities, and special marks and peculiar features.

In the great majority of cases such a description can be well made by a layman. When, however, decomposition is advanced, or the cadaver mutilated, or burned, or only portions thereof are at hand, anatomical knowledge is necessary and by means of it many of the above points may be cleared up or approximately judged that would otherwise remain unknown.

Race and nationality are determined by well-known characteristics, for which the reader must be referred to works on anthropology.

Sex.—In well-preserved cadavers the determination of sex, except in cases of hermaphroditism, is readily made. Where, however, the body is not well preserved, or where parts of the cadaver only are at hand, there are various points which may aid in determining the sex. The growth and distribution of the hair are usually characteristic of sex, and yet in exceptional cases they may fail to enlighten us upon this question. The long hair of the scalp and its arrangement, the absence of hair (except fine, downy hair) on the face, the sharp line of demarcation of the hair upon the mons veneris, and its fine, downy character upon the extremities, are characteristic of the female. The presence of coarse hair upon the face, chest, and extremities, and the prolongation of hair from the mons veneris along the median line to the umbilicus, or its more abundant distribution over the belly as well, are characteristic of the male. With progressive maceration the epidermis, and together with it the hair and nails, become separated from the cutis and fall off, leaving a smooth surface, especially in cadavers that have been exposed in the water. Beard and moustache may be lost after four or five days of such exposure in hot weather, after two weeks in cool weather, and after the lapse of a month or more in cold weather. Exposure to flame may cause complete disappearance of hair. If the hair is thicker, more oily, or arranged in a braid, it is more likely to be partially preserved.

The general external form of the cadaver, or parts thereof, may be distinctly of feminine or masculine type, yet dependence upon this alone may lead to error. Before puberty the male and the female forms are very much alike. As regards the breasts, they may be undeveloped or atrophic in the female, and from abundance of subcutaneous fat the male breasts may simulate those of the female. The presence, at birth, of a mammary gland, and of a secretion that can be expressed, is common to both sexes.

The genital apparatus (or characteristic parts thereof) is of course the most certain proof of sex. The external genitals may have been lost or rendered indistinguishable by putrefaction, by maggots or rats, by incineration, or by mutilation or removal. The uterus, from its firm consistence and protected situation, has been recognized in cadavers that were far advanced in putrefaction—even as late as at the end of nine months after death (Caspar and Liman). According to the authority of Hofmann, there have been instances in which the cadaver was considerably charred, with ruptured abdominal walls and external charring of the uterus, and yet upon section this organ was easily identified through the intact condition of the endometrium and arbor vitæ. The ovaries have also been identified after considerable charring of the cadaver. The deep urethra, with its caput gallinaginis and the deep parts of the corpora cavernosa (crura penis), may be distinguishable even when there has been extensive destruction of other parts of the body.

Examination of the skeleton or of parts thereof may lead to a decision. In the female, the skeleton is smaller and the bones are lighter in weight. The thorax is proportionally shorter and wider, especially in its upper part. The curvature of the ribs on the flat in the posterior part is more pronounced, the curvature on the edge (downward) less pronounced, than in the male (Henle). The first and second ribs are longer relatively and absolutely than in the male (Meckel). The sternum is shorter and broader, the difference depending upon the body (gladiolus) of the bone. The xipho-sternal articulation is on a higher level (that of the curve of the fourth rib), while in the male it is on a line with the curve of the fifth rib. The clavicle is less markedly curved, and the entire thorax, in proportion to the size of the pelvis, is much smaller. The chief difference is to be found in the pelves of the two sexes, and this difference is greatest at and after puberty. In the female the transverse dimensions are greater than the vertical; the ilium is more inclined outward toward the horizontal plane; the promontory of the sacrum encroaches less upon the pelvic inlet; the true pelvis is shorter but more roomy, and its outlet is absolutely as well as relatively wider; the sacrum is wider and shorter, and its curvature less marked; the ischiac spines encroach less upon the cavity; the pubic arch is wider and less angular, and its edges are everted; and the tuberosities of the ischia and the acetabula are wider apart. In the male, the entire pelvis is more massive, the eminences and depressions for muscular attachments are more marked, the pelvic cavity is deeper and narrower, and the obturator foramina are larger and more oval (less triangular) in shape.

The following average measurements of the true pelvis are taken from Toldt, and, in the determination of sex, are to be regarded relatively, since individual measurements may vary markedly in the same sex:

Part.	Diameter.	Female.	Male.
Inlet...	Antero-posterior.	118 mm 4.72 in.	113 mm. = 4.52 in.
	Transverse......	135 " = 5.4 "	127 " = 5.08 "
	Oblique	124 " 4.96 "	120 " = 4.8 "
Cavity .	Antero-posterior.	126 " = 5.04 "	114 " = 4.56 "
	Transverse	120 " = 4.8 "	109 " = 4.36 "
Outlet..	Antero-posterior.	90–110 " = 3.6–4.4 "	75–95 " = 3–3.8"
	Transverse	110 " = 4.4 "	82 " = 3.28 "

Height.—The relaxation of the ligaments and other tissues following death, more especially after rigor mortis has ceased and decomposition has commenced, taken in connection with swelling or emphysema of the scalp, might be responsible for a slight increase in height post mortem. The mode of measuring the height is as follows: The cadaver is laid out straight upon a flat surface, and the measurement is made between the perpendicular line dropped from the top of the vertex and the plantar surface of the heel, the foot being at right angles with the leg. In certain cases it is desirable to estimate the total height of a body of which only isolated parts are available. The following proportions will be found useful as a basis for making such a calculation: The distance between the tips of the middle fingers, the upper extremities being extended at right angles to the trunk, equals the height. If an upper extremity alone is at hand, its length doubled plus the distance between the two glenoid surfaces would give the height. How much should be allowed for this latter distance is difficult to estimate. The length of the two clavicles plus that of the interclavicular notch—a total which would average twelve inches—would be too much, and consequently the total height of the body, estimated according to this formula, would also be too great.

Other formulæ are the following: The length of the middle finger is one-nineteenth of the height; the length of the forearm, from the tip of the olecranon to the tip of the middle finger, is five-nineteenths of the height; the upper border of the symphysis pubis is about the middle point of the total length of the body, after full growth; the length of the lower extremity, from the head of the femur to the plantar surface of the heel, is about one-half the height (according to Orfila, the lower part, measuring from the symphysis, is shorter, by an average of two and one-third inches, than the upper, especially in women); the length of the femur is about one-fourth of the total height, after full growth.

Tables of the relative proportions of the dimensions of single bones to the total height are given by Orfila, Toldt, and others. For the determination of the total height from single bones the age must be known. In exceptional cases the age may be determined from single bones, and in such cases comparison of measurements with standard tables may be found very useful in estimating total height. However, the proportions given above are practically as reliable as the data furnished in these tables.

Age.—The most important points upon which estimates in regard to age—at least up to the time of complete growth—may be based, are the appearance of the centres of ossification, the progress which they have made toward complete ossification, and their final union with neighboring centres. In young subjects the examination of the teeth warrants important conclusions. The results of anatomical investigation are too extensive to be included in the present article.

Conclusions based upon the height of the cadaver are less reliable. If we take 50 cm. as the average height at birth, in five years this height will be doubled (100 cm.). In the first year the increase amounts to from 1 to 2 cm. a month, or from 12 to 24 cm. for the year. After the first year the increase varies from 7 to 8 cm. for each year. During the ten years following the first five the height increases to thrice that at birth (*i.e.*, to 150 cm.), averaging 5 cm. for each year in the ten. At puberty, growth is again more rapid, up to the eighteenth year, and then again it proceeds more slowly up to the time of complete growth; the usual height attained by males being from 157 to 180 cm., while that attained by females amounts to from 153 to 166 cm. (Hofmann).

Care should be taken lest premature loss of hair, grayness, loss of teeth, or marasmus lead one into error in estimating age. The senile increase in the angle between the body and the ramus of the inferior maxilla, the atrophy of the alveolar processes, and the decrease in the angle between neck and shaft of the femur are important indications of advanced age.

The general condition of the cadaver—whether obese, well, or poorly nourished, or thin or marantic—may afford important aid in the work of identification.

The appearances produced by putrefaction should not be confused with obesity, or those due to mummification with marasmus or with advanced age. The appearance of nutrition may be completely changed in cadavers after exposure to flame, and due allowance should be made therefor.

In regard to the color of the hair in exhumed cadavers, it has been found that it changes to a reddish brown, the effect of exposure to putrefactive substances or to the soil. Time alone will change the color of dead hair, as may be seen in wigs and in the hair of Egyptian mummies. Heat causes a change of color toward a reddish tint.

Special marks for identification—teeth, moles, warts, scars, and tattoo marks—should be accurately described. Tattoo marks may disappear. According to Caspar, this happens once in nine cases; according to Hutin, once in ten and a half cases; and according to Tardieu, once in twenty-five cases. Soluble pigments are more likely to disappear. Even insoluble pigments may be carried through the lymphatics and lodge in the peripheral parts of neighboring lymph nodes.

The appearance of the hands and finger nails, or the presence of callosities, stains, etc., may warrant a shrewd guess as to occupation. *Otto H. Schultze.*

CADE, OIL OF.—OLEUM CADINUM. *Oleum Juniperi Empyreumaticum.* "A product of the dry distillation of the wood of *Juniperus Oxycedrus* L. (fam. *Coniferæ*)" (U. S. P.). The British Pharmacopœia includes "some other species" in the source.

J. Oxycedrus resembles in general the common juniper of Europe, but has larger, reddish-brown, shining fruits (1.25 cm. in diameter—0.5 in.). It is an inhabitant of the Mediterranean basin, growing in waste places and upon stony hillsides.

Its tar has been used for centuries by the peasants of Southern France for the "sheep itch" and other cutaneous affections of their cattle, but its employment in medicine, although occasional and also of old date, has only been extensive since its recommendation by the German school of dermatologists in the treatment of eczemas. It is prepared by a method similar to that used in the manufacture of ordinary tar; that is, by distillation *per descensum*, in rude stills or ovens, from the bottom of which it is collected and then sold without further purification. The principal centre of its production is Nîmes.

It is a thin tar, often black in mass, but brown or brownish yellow and transparent, in thin layers; and is more fragrant and pleasant in odor than common wood tar, which it otherwise resembles. The taste is acrid and empyreumatic. Its composition is not notably different from that of the tars of other conifers. *Cadinene* ($C_{15}H_{24}$) is its important odorous constituent. The principal use to which it is put in medicine is that mentioned above—for the local treatment of eczema in the scaly stage. It is also used in other chronic inflammatory and exfoliating skin diseases. It may be applied by rubbing in with the fingers or a cloth, or, what is better, with a stiff-haired brush. If desirable to dilute it, some bland oil may be mixed with it, or it may be made into an ointment with lard or tallow, or with vaseline. Soaps containing it are also considerably used. Stockings, gloves, and bandages saturated with it are sometimes worn. Besides its stimulating properties, oil of cade is a good parasiticide, an efficient antiseptic, and a local anæsthetic—properties which it undoubtedly owes to the creosote and similar substances which it contains. It is never used internally. *W. P. Bolles*

CADMIUM.—*Cadmium Sulphate* is the only salt of this metal that merits notice in medicinal relation. It was official in the United States Pharmacopœia of 1870, and, though dropped in the revision of 1880, it is still considerably employed. The salt, formula $CdSO_4,4H_2O$, occurs in small colorless, rhomboidal crystals, efflorescent on exposure. It is freely soluble in water, and has a subacid and astringent and metallic taste. In properties it most closely resembles zinc sulphate, being an irritant astringent. Taken internally, it will determine vomiting, after the manner of zinc sulphate, and in overdose will prove poisonous. Its claim for recognition in medicine rests on an alleged peculiar potency in determining the absorption of such corneal opacities as are capable of undergoing that process—a potency certainly not much, if at all, greater than that possessed by the commoner salts, silver nitrate or zinc sulphate.

Cadmium sulphate is generally used in solution of from one-half to one per-cent. strength. *Edward Curtis.*

CADMIUM, POISONING BY.—Cadmium and its salts are comparatively unimportant from a medico-legal point of view. Their uses are limited, and they are seldom met with outside of the chemical laboratory. The metal is employed occasionally in alloys to reduce their fusing point, and an amalgam has been used by dentists for filling teeth. The most important compounds are the iodide and bromide, which are used in photography for iodizing and bromizing collodion. The sulphate of cadmium has been recommended, used internally, in the treatment of syphilis, rheumatism, and gout (Grimaud). It has been chiefly used externally, however, as an astringent and stimulant, in the treatment of conjunctivitis, and ulcers and opacities of the cornea. The iodide of cadmium, in the form of an ointment, has been recommended for external use, particularly in the treatment of scrofulous enlargement of the glands (Garrod, Guibert). The sulphide of cadmium has been used, to a limited extent, as a yellow pigment. Excepting the sulphide, the compounds mentioned are colorless, soluble in water, and possess a disagreeable metallic taste.

Symptoms.—Preparations of cadmium have given rise, occasionally, to accidental poisoning. They appear to act as irritants, resembling in general the salts of zinc. Sixty milligrams (0.9 grain) of the sulphate, taken internally, caused in one hour salivation, colic, and diarrhœa; and after four hours, vomiting accompanied by intense gastralgia and tenesmus (Burdach). Vomiting, diarrhœa, vertigo, labored respiration, loss of strength, and cramps followed the inhalation of the dust arising from a polishing powder containing carbonate of cadmium (Sovet). Two ladies took an uncertain but small dose of bromide of cadmium by mistake for bromide of ammonium. It caused severe pain and a burning sensation in the stomach, accompanied by vomiting and purging which lasted for five hours. During a part of this time the pulse was imperceptible. There were no cerebral symptoms. Both patients were confined to their beds for several days, during which time their stomachs continued irritable (Wheeler). There is only one fatal case of cadmium poisoning recorded, so far as the writer has been able to learn. The patient, a lad fourteen years of age, took an unknown but probably large dose of chloride of cadmium, which had been sold for Epsom salts. It caused immediate vomiting. On admission to the hospital a short time after, he was in a state of collapse, with cold, clammy skin; radial pulse scarcely perceptible; respiration feeble, slow, and sighing. There was no stertor. The mucous membrane of the mouth was pale and sodden, the tongue greatly swollen. He was apparently unconscious, though when shaken and aroused by dashing cold water upon the face, he replied rationally, in a hoarse whisper, to any questions put to him. There was extreme restlessness. Deglutition was impeded. Death took place in about an hour and a half after the ingestion of the poison. At the post-mortem examination the vessels of the brain were found filled with blood; the left lung congested (Mr. J. Hinder, *Indian Medical Gazette*, Calcutta, 1866, i., 156).

Experiments on Animals.—Marmé has studied the action of the salts of cadmium by experiments on animals. He concludes that the sulphide is non-poisonous. Administered to animals with their food for a week, in doses of many drachms, it caused no inconvenience. Its insolubility in water, weak acids, alkaline salts, and oil renders its use as a pigment free from danger. All compounds of cadmium which are soluble in water or weak acids at the temperature of the body are poisonous. Taken into the stomach they cause, in small doses, vomiting; in large doses, all the symptoms of gastro-enteritis. If quantities sufficiently large to be poisonous, without causing death rapidly, are injected beneath the skin or into the blood-vessels, they produce inflammation of the stomach and intestines, and frequently hemorrhages, erosions, and ulcerations. Small doses injected into the blood-vessels are fatal to animals. Thirty milligrams (0.5 grain) killed a dog; 16 mgm., a cat; 10 to 20 mgm., a rabbit; 30 to 60 mgm. (0.5 to 0.9 gr.), administered by the mouth, killed a rabbit weighing 1,500 to 1,800 gm. (3.3 to 3.9 lbs. avoir.). The repeated absorption of small doses may give rise to chronic poisoning, which, in animals, is characterized by disturbed digestion, emaciation, and death. The post-mortem appearances observed were: a more or less extensive gastro-enteritis, sometimes subpleural hemorrhages, infarctions of the lungs, frequently fatty degeneration of the liver and heart, and diffuse nephritis. Elimination commences very soon and takes place chiefly through the kidneys. After death, cadmium can be detected in the blood, heart, liver, and kidneys.

Treatment.—This should be much the same as in cases of poisoning by salts of zinc. Vomiting should be assisted, if necessary, by the free administration of warm water, with milk or mucilaginous liquids; or the stomach may be emptied by means of the stomach pump. The subsequent irritation may be allayed by the use of opium. Marmé recommends, in cases of acute poisoning, the alkaline carbonates with white of eggs. The subcutaneous injection of dilute solutions of soda, when employed early, was found, in the case of animals, completely to arrest the poisonous action of the cadmium salts. *William B. Hills.*

CÆCUM, DISEASES OF. See *Appendicitis*; *Colitis*; and *Colon, Surgery of the*.

CÆSAREAN SECTION.—Cæsarean section is a term used for operations which remove a fœtus from the uterus through the abdominal wall, the peritoneal cavity being opened in all cases. Historically it is one of the oldest of obstetrical operations recorded.

It is generally supposed to have received its name from Cæsar, who was believed to have been born by abdominal section. But, whether this be true or not, it was performed many years before his time. Furthermore, the name, according to Pliny, was derived from the Latin *cædare*, "to cut," which makes the term Cæsarean section rather meaningless and the use of the capital C inappropriate, but usage gives it a definite meaning and place.

Until the Middle Ages the operation was largely performed only to deliver a child when the mother was dying. The Roman laws forbade the burial of a pregnant woman until the child had been removed. The first performance of the operation on a living woman which is recorded was in 1500 A.D., the operator being a butcher named Jacob Nufer, in Switzerland. In Germany, Trautmann, of Wittenberg, inaugurated the procedure in the year 1610. The patient lived three weeks.

Until the advent of antiseptic surgery in recent times the mortality following the operation was too great to encourage its employment in any but extreme circumstances.

Until the introduction of recent modifications the various steps in the operation were: 1. Section of the abdominal wall, usually in the median line between the pubes and umbilicus. 2. Section of the uterus *in situ*, the incision being made upon the middle, anterior surface from above downward. 3. Removal of the child and placenta. 4. In some cases suturing of the uterine wound, and in others leaving it to close by general contraction of the uterus; and suturing of the abdominal wound.

From a historical standpoint the most interesting question has been the treatment of the uterine wound. So recent a work as Cazeaux and Tarnier's, seventh edition, 1884, states that, "the wound in the uterus requires no other attention than that of being well cleansed"; while Playfair, third American edition, 1880, considers the question of suture "a mooted point." To Kehrer ("Ueber ein modificirtes Verfahren beim Kaiserschnitte," *Arch. f. Gynäk.*, vol. xix., p. 177, Berlin, 1882), Sänger ("Der Kaiserschnitt bei Uterus-Fibromen nebst vergleichender Methodik der Sectio-Cæsarea und Porro-Operation," Leipsic, 1882), and Leopold ("Ein Kaiserschnitt mit Uterusnaht nach Unterminirung der Serosa und Resection der Muscularis"; "Zwei weitere glückliche Kaiserschnitte," etc., *Arch. f. Gynäk.*, vol. xix., p. 400, 1882, and vol. xxiv., p. 427, 1884), belong the chief credit for the improvement in the treatment of the uterine wound which has rendered the present splendid results possible.

The three improvements that have brought the mortality of Cæsarean section from nearly one hundred per cent. to about five per cent. are: antisepsis and asepsis; complete muscular and serous suturing; coaptation in the uterine wound, and operation at the selected time, instead of when patients were mostly moribund, or exhausted by long labors; and the Porro hysterectomy.

Methods of Operating.—The Sänger Cæsarean section. To Sänger has been awarded the honor of title of the simple cœlio-hysterotomy form of Cæsarean section. For performing this operation the patient is prepared as for any abdominal section. The urine should be carefully tested, the bowels thoroughly emptied, the abdomen washed with green soap and alcohol or ether, and bound with gauze (1 to 1,000 bichloride) twelve hours before operating. The pubes should be shaved, and the vulva and vagina made as aseptic as possible. This latter is best accomplished by first douching with hot bichloride solution and by dusting boric-acid powder into all the crevices of the introitus vaginæ and the vulva. The urine should after this be drawn with a soft catheter. The instruments needed are: scalpels, two mouse-toothed dissecting forceps, one dozen artery forceps, scissors, long-curved needles, as well as some that are small and short, needle-holders, sutures of medium-sized silk, silkworm gut, and catgut; two pieces of either solid rubber ligatures or tubing, each about eighteen inches long; several pedicle clamps; right and left aneurism needles, and one large vulsella forceps.

When to Operate.—There are some advantages in operating when the patient is in labor, the choice moment being when the uterus is awakened to active rhythmic pains, but previous to any exhaustion.

There is less liability to failure of the uterus to contract after section and removal of its contents. The cervix is also more succulent, and will permit delivery of the placenta *per vias naturales* if that proves best. On the other hand, it is difficult to make as thorough preparation for operation and perform it before any exhaustion of the patient occurs, if the time is decided by the occurrence of labor, which may be at an inconvenient hour. Generally, when the operation has already been decided upon, the operator selects his time. This time should, of course, be as near term as possible, unless there are special indications to the contrary.

Steps of the Operation.—The abdominal incision is made in the median line, running from one inch and a half below the umbilicus to just above the pubes. Usually the uterus lies in contact with the abdominal wall, the omentum and intestines being above and somewhat to the left of that body, but it is not wise to assume this and cut at one stroke through the abdominal wall. There is no need of such effort at speed.

There are at this stage two methods of handling the uterus: one to incise it *in situ*, and the other to lift it out of the abdominal cavity and then incise it. The first method can be used when the uterus is free from infection and the fœtus of moderate size. It has the advantage of requiring less length of incision in the abdominal wall than the second method, and of causing less exposure and displacement of the intestines. The second method has the advantage of more thoroughly keeping the fluids from the uterus out of the abdominal cavity, and permits better control of uterine hemorrhage. There are also two methods employed for the control of hemorrhage. By one the uterus is constricted by means of a rubber ligature (this is about one-eighth of an inch thick and eighteen inches long), or by rubber tubing, which is passed around the lower portion of the uterus, and either tied tight with the knot in front, or a single turn in the knot is made and constriction applied according to the need during the operation. By the other method an assistant grasps the lateral attachments of the uterus with the thumbs and fingers of both hands and makes compression of the uterine and ovarian arteries as required. The advantages of the rubber constrictor are: that it does not require an individual assistant, that it more surely prevents hemorrhage, and that it is less in the way of the operator than are the hands of an assistant. It has a distinct disadvantage in its liability to cause asphyxiation of the child; and it has a tendency to cause partial paralysis of the uterus, and so favors bleeding by preventing uterine contraction after the organ is emptied. A good assistant holding the uterus can both estimate the degree of compression required and apply it with lessened liability of fœtal asphyxiation. He can also be of service in steadying the uterus for the operator.

The uterine incision should be a clean cut, which should be made at first only large enough to admit two fingers, when the opening can then be enlarged with the fingers holding it open, and either a bistoury or blunt scissors used for making the enlargement.

Many different incisions of the uterus have been advocated, but only one—the longitudinal—can be employed with the uterus *in situ*. Following is a list of the various incisions advocated: the longitudinal middle third (Sänger); the posterior surface (Cohnstein); the transverse lower segment (Kehrer); the transverse fundal (Fritsch); the sagittal fundal (Müller-Caruso); and the longitudinal, from fundus to Bandl's ring (Bar). Originality has evidently found its limit in methods of making uterine incisions; even the cervical incision of the discarded laparo-elytrotomy is excluded from the pioneer.

Of the above methods only those of Bar, Sänger, and Fritsch need to be considered. The Sänger incision is not rightfully his, as it was performed long before his time. The choice between it and that of Bar would depend solely upon the location of the placenta, if that could be determined—which it usually cannot. There is less certainty of contraction of the lower portion of the uterus, which gives Bar's incision an advantage for securing both greater avoidance of hemorrhage and better behavior of the wound when sutured. It is claimed for Fritsch's transverse incision that there is less hemorrhage than in the longitudinal incision because the uterine vessels pursue a transverse course; also that there is least liability of finding the placenta in this region. Neither of these views has any special foundation in fact. It might be claimed for the method that the risk of infection is lessened by having the line of incision run at right angles to the abdominal incision, whereby possible infection of the latter would be less liable to come in contact with the former. Hahn (*Centralbl. für Gynäkol.*, December 9th, 1899) gives a summary of a total of fifty-one cases of Cæsarean section performed by Fritsch's method up to date. Two died, both from circumscribed peritonitis. The summary is inconclusive so far as showing any special advantage over Bar's incision. In the absence of special indications, Bar's incision is best.

While the uterus is being incised an assistant should endeavor to keep the lips of the abdominal wound closely coaptated to the uterus to prevent the entrance of fluids into the abdominal cavity.

There are certain advantages in bringing the uterus out of the abdominal cavity before incising it, and likewise disadvantages. The advantages are: the uterus can be better handled, its contents can be kept out of the abdominal cavity, and some time can be saved. The disadvantages are: the long abdominal incision, and the greater liability to hernia and to adhesions.

The disadvantages are subject to control by perfect technique, so that the well-known surgical rule can be applied, that free incision with perfect technique appeals to first-class operators as against the opposite method. The method with the uterus brought out should always be selected when there is any suspicion of an infected uterine cavity.

The length of the incision of the abdominal wall can best be determined in each case. Before drawing the fundus out of its bed it is well to pass two long sutures through the upper wound. These can be used, after removal of the uterus from its bed, to hold the intestines back in place. When the uterus is drawn out it should be covered with warm, sterile cloths. Pads or mats of sterile gauze should be packed underneath, to protect the abdominal cavity from fluids. In cases of special sepsis, in which it is necessary to incise the uterus before ablating it in order to save the child, it is a good measure to slip a large sheet of pure rubber, properly sterilized and punctured, over the entire uterus down to the cervical portion. It will automatically keep out every drop of fluid from the cavity.

Location of the Placenta.—As the result of unusual opportunity and very careful observation, G. Leopold has been able to formulate a rule for determining the placental site when the uterus has been brought into view by abdominal section. There is a constant relation between the placental site and the direction of the tubes, the latter extending backward when the after-birth is on the anterior wall, and remaining laterally, or rather directed forward, when it is on the posterior wall. In some cases there is a bulging of the uterus over the site occupied by the placenta. These are means of diagnosis which come within reach when the uterus has been exposed by abdominal section, and which can therefore be utilized in Cæsarean section. If the placenta were thus indicated as being upon the anterior middle surface of the uterus, it would be well to make the incision transversely across the fundus (Fritsch's incision), or transversely across the posterior fundus (Cohnstein's).

In making the incision through the uterus the placenta must be disregarded once the incision has been started. It can either be cut through, or separated if its edge is near the wound. The wound being of sufficient size, the child is drawn out either head or foot first, whichever way proves most convenient. The placenta may then either be removed through the opening or, the cord dropped back within the womb, be extracted through the cervix.

In the treatment of the uterine wound it is only a matter of historical interest that it was formerly thought unnecessary to suture this wound. It was thought that the uterus, being a contracting compound of variously running muscular fibres, would close the wound without the assistance of any sutures; but this view has been found to be altogether wrong, and no further discussion of it is permissible. The opposite treatment, that of water-tight suturing of the wound, is now altogether employed.

To get the most absolute coaptation and impervious union of the lips of the wound, Sänger went to the extreme of advocating the dissection of a thin strip of muscle from each raw surface of the wound in order that the peritoneum could be enfolded on both sides and prompt sealing of the wound by peritoneal agglutination thereby secured. Even this time-taking and troublesome dissection has already become historical. It is found correct in aim, but entirely unnecessary, as the same degree of coaptation can be secured by enfolding superficial sutures.

It should be borne in mind that perfect closure of the uterine wound is essential to success, and the method employed should not be slighted by any one.

First, a row of deep sutures of silk should be inserted, extensive enough to include the muscle, but not the endometrium or decidua. These sutures should be placed —interruptedly—about 1.5 cm. (.65 in.) apart, and should emerge at the same distance from the edges of the wound. Between these should be inserted a similar series of sutures at half the depth of the first set. In inserting these sutures care should be taken to have the opposite surfaces meet without irregularity in spacing, lest wrinkling result and afford a pocket for infected secretion. As the uterus will sustain constant rhythmical contractions and relaxations, it is well to tie the sutures a little too tightly rather than too loosely. A slight blanching of the included tissues is evidence of proper tension by the sutures. When both layers of the deep and half-deep sutures have been tied, a superficial row which includes only the peritoneum should be introduced. These are intended to enfold the peritoneum and bury the other sutures. Fine silk should be used. These sutures include just enough peritoneum to secure a good hold, and run entirely over the deeper layers. They may be either interrupted or continuous, following the method of Lembert in suturing the intestines. The latter method is quite as effective as interrupted suturing, and has the advantage of saving time.

As in every abdominal operation, very careful cleansing of all parts by gauze sponging should be employed, the region behind the uterus receiving special attention. Hunter Robb advises drawing the omentum down behind instead of in front of the uterus in making the final toilet of the abdominal cavity, as proving less likely to cause omental adhesions and subsequent hypogastric and epigastric pains after the uterus has contracted.

In removing the placenta, it is possible, with a little care, to avoid bringing the hands in contact with the uterine wall by keeping them within the amnion, the placenta being grasped on its fœtal surface with the amnion entirely enveloping the hands.

Irrigation of the uterus after section is not usually indicated, inasmuch as this method of operating should not be performed if infection has already taken place, the Porro method being employed instead. There may be circumstances present in the operation interfering with perfect asepsis, in which case thorough douching with bichloride solution—1 to 10,000—should be employed.

In the after-treatment of the patient but little variation from ordinary management in abdominal operations is indicated. If the bowels were not properly—*i.e.*, thoroughly—emptied previous to operation (this is peculiarly liable to be the case in Cæsarean section, where so many cases are emergency operations), efforts should be made to secure thorough cleansing at once. Otherwise the second day will be best for the administration of cathartics.

The vagina should be douched after operation to remove blood accumulations, and then treated as in ordinary labors in which douching is not necessary; but careful dressing of the vulva with sterile gauze and cotton pads is essential. Voluntary micturition is preferable to catheterization. There is a physiological advantage in placing the child to the breast at regular intervals, as this stimulates the uterus to healthy contraction and favors involution. The patient should not be asked, however, to feed the child from the breasts, unless she is quite able to do so without feeling the drain.

The patient should be allowed partially to sit up in bed after eight or nine days, according to the conditions. To avoid abdominal hernia, it is best not to hurry getting the patient on her feet, the fourth week being usually time enough. An abdominal bandage, or truss, should be worn for a while.

CŒLIO-HYSTERECTOMY (the Porro operation).—In 1876 a modification of the classical Cæsarean section was performed by Edward Porro, which consisted in ligation of the uterine and ovarian arteries and removal of the uterus at the cervix, the stump being brought into the abdominal wound and there fixed.

There are two methods of performing this operation: one, the original Porro method, in which the same steps as in the method just described, up to the removal of the child, are taken, after which the ovarian and uterine arteries in the broad ligaments are tied, and the uterus then cut away just above the ligature; and the other known as the Porro-Müller method, in which the abdominal incision is made sufficiently large to permit bringing the uterus out of the abdominal cavity before removing the child, when the latter, if still alive, is removed by opening the uterus; or if the child is dead, or the uterus is dangerously septic, the entire uterus is cut away without opening it.

When the Porro method—removal of the uterine contents with the uterus *in situ*—is employed, great care is necessary to prevent contact of any of the uterine fluids with the abdominal cavity, inasmuch as this operation is generally done in preference to the so-called Sänger operation because the uterus is believed to be septic. It is better, when doing the operation, to ligate the neck of the uterus more tightly than is done in the Sänger operation, as it is most desirable to avoid flowing into the abdominal cavity, while there is no need of preserving uterine tonicity.

In doing this operation there is no necessity for care in making the opening into the uterus, and it is permissible to tear the opening with the hand instead of cutting to the desired size with knife or scissors. This may save some time and lessen hemorrhage. It is also well to draw a pad of sterile gauze down behind the uterus before making the incision into it. This will best prevent the entrance of fluids into the abdominal cavity. After the uterus has been emptied it should be cut away with scissors at about one inch above the line of constriction, the tubes and ovaries being included. The vessels should then be ligated, including those in the stump. The raw surface of the stump is next seared with pure carbolic acid. The abdominal wound is then sutured down to the stump. Knitting needles, or pins six inches or more in length, are passed through the stump, including the ligature, and are protected from cutting into the abdominal wall by pads of gutta-percha or closely folded gauze. The stump is generally well dusted with iodoform and boric-acid powders, though there is a developing tendency to discard iodoform at the present time. The entire wound is then covered with sterile gauze pads and absorbent cotton. These dressings may require removal and fresh ones to be put in their place in two or three days, especially if sepsis develops in the stump.

A modification of this method of treating the stump is known as the subperitoneal method, in which, instead of bringing the stump into the abdominal wound and fixing it there, it is left *in situ*, and a layer of peritoneum from the posterior surface of the lower uterus is dissected free from the uterus before the constrictor is applied, and then closely stitched over the stump to the peritoneum in front. This method requires, in place of the constriction ligature around the neck of the uterus, the application of clamps to the vessels in the broad ligaments; then, after removal of the uterine contents, the peritoneal flaps are dissected loose. The constrictor can then be applied without involving the flaps. This method requires more time than the older one, but is preferable when feasible.

Complete Hysterectomy.—The removal of the entire uterus and cervix is necessary in conditions such as cancer involving the cervix. When this is done, instead of ligaturing the stump the vessels are tied in the broad ligament and the uterus dissected out complete, as in ordinary hysterectomies in gynæcological work.

INDICATIONS FOR CÆSAREAN SECTION.—Certain cases of pregnancy are met with in which the physician has the choice of only one method of relief—Cæsarean section.

Tumors and Diseases.—Tumors of the lower segment of the uterus which cannot be removed by vaginal operation, and which are of such size as to prevent dilatation of the cervix sufficient to permit passage of the fœtus, necessitate cœlio-hysterotomy. Fibroids are most frequent in this list. Ovarian tumors impacted in advance of the head, and occupying the pelvic basin to the obstruction of the fœtus; rarely a dislocated and adherent kidney; intestinal displacement; carcinomata of the cervix, rectum, sigmoid flexure, and vagina, and certain obstructive growths following old cases of appendicitis, compose most of the abnormalities necessitating Cæsarean section. Exostoses may also compel the operation. Cicatrices of the vagina may be of sufficient size to compel Cæsarean section. It is not worth while to classify some of these obstructions as "absolute" indicators of Cæsarean section, because every case offers an individual equation, and must be decided by itself.

It may be that slitting the cervix in some cases of tumor, such as myoma, will be less dangerous than Cæsarean section; or a tumor of the ovary prolapsed into the pelvis may be removed with less danger than a Cæsarean section involves. In tumors of the lower uterus the imminent danger of rupture of that organ in cervical dilatation must be given much weight. In cicatrices of the vagina it may seem feasible to cut and dilate them, but they are liable to tear much beyond safe limits in the passage of the fœtus.

In all these various indications the general rule prevails among experienced operators that a controllable operation like Cæsarean section is much safer than severe straining and mashing of tissue involved in drawing a fœtal body through an abnormally obstructed vagina. Incisions of the cervix or of vaginal cicatrices, with blind traction and distention, cannot equal aseptic, clean abdominal incisions and neat suturing of wounds, even though the latter be great in extent.

Pelvic Contraction and Large Head.—When a pelvis is too small to allow passage of the head of the fœtus by symphysiotomy, or when craniotomy would be as difficult and dangerous as a Cæsarean section, the indications for the latter operation may be classed as absolute. But it is almost useless to define such conditions by fixed pelvic diameters. A conjugata vera of but two inches would be "absolute," but between two and one-half and three inches it is not possible to classify the indications. The only proper method of determining the dimension indications for Cæsarean section is to learn the relative proportions existing between fœtal head and pelvic calibre; and pelvic measurement is only one-half of the problem.

Contraction of the pelvic canal of sufficient degree to render craniotomy as dangerous as Cæsarean section is one of the rarest abnormalities in obstetrics. The degree of contraction which renders the operation of symphysiotomy out of the question should be determined. This method of delivery occupies a field limited to such degree of disproportion as will permit passage of the fœtal head after section of the pubic joint without necessitating a separation of the pubic bones of more than two and three-fourth inches. A greater separation of these bones involves such risk to the sacro-iliac joints and the vaginal wall and bladder as to condemn the operation. Cæsarean section should be the absolute choice in such cases.

Symphysiotomy should be performed only when the patient is in labor, and the most useful and the safest method of determining how much separation of the pubic bone would be required is direct palpation of the head and pelvic inlet with the hand in the vagina. Approximately indicating by figures the limits, we would state that a conjugata vera of three inches and a fœtal biparietal diameter of from three and one-half to four inches would not cause too great separation of the pubic joint. Wotherspoon delivered a child weighing fifteen and one-half pounds with a separation of nearly five inches; and the patient recovered, but with a torn vagina, urethral fistula, and one-half of an inch separation of the pubic bones. Such cases get beyond the control of the operator, and are not justifiable when foreseen.

The comparative mortality and morbidity of Cæsarean section, induced labor, and symphysiotomy depend, in the answer, upon many variable points. Induced premature labor is safest for the mother and most dangerous for the child in cases requiring delivery before the thirty-second week. Cæsarean section is most dangerous for the mother and safest for the child; symphysiotomy is safer for the mother than Cæsarean section, and somewhat more dangerous than induced premature delivery. It is less dangerous for the child than the latter method, and more so than is Cæsarean section.

The essential operative mortality (that per cent. of fatalities which will follow the surgical work of the best operators in cases taken at the time most favorable, and which must follow present methods of performance in these several ways of delivery) must be the foundation for selection of method.

Induced premature labor for dystocia is essentially always of the above class, as it is performed voluntarily and at the convenience of operator and patient. The mortality is about 4 per cent., but should not be more than 1 per cent. higher than pertains to spontaneous ordinary labors. Its relative safety for the mother is unquestioned.

The mortality for the child is, and always will be, very high.

Twenty-five per cent. of all babies born die within the first year. The death rate within full term for six-months time babies is nearly 90 per cent., at seven months 75 per cent., and at eight months 50 per cent. These figures are higher than those given by French writers, but they aim to include private as well as hospital cases. Induced labor at a period nearer term than eight months would not indicate Cæsarean section as an alternative operation. Efforts have been made by Prochownick and others to keep the fœtal cranial bones soft up to term by diet, and so accomplish delivery without operation. The results obtained justify further effort in this direction.

The essential mortality from symphysiotomy is about 2.5 per cent.; this in the hands of experienced operators and when the method was properly selected. Pinard gives 5 per cent. as the mortality of 160 symphysiotomies done at the Baudelocque Clinic 1892–1899, excluding 7 deaths due to outside causes. The writer has operated 13 times without a death from symphysiotomy. The general fœtal mortality is given as 14.5 per cent.

The essential mortality from the Sänger Cæsarean section can be given only by estimate. Reynolds ("Obstetrics," Vol. II., No. 1), taking the cases of Leopold, Everke, and himself in which the patients were free from sepsis and exhaustion from labor, reports 88 cases with but 2 deaths which occurred some years ago from operative sepsis. In the hands of operators in general we would expect a percentage mortality from selected cases of about 5. For the children it should scarcely exceed the results in normal labors.

The actual mortality from the Sänger operation is from 6 to 8 per cent. in the work of the leading operators. From all sources the actual mortality from Cæsarean section is from 25 to 33 per cent. to-day. From symphysiotomy it is about 10 per cent. The mortality from the Porro operation is necessarily higher than from the Sänger operation, even in the best of hands, inasmuch as the cause of its selection is often the septic condition of the uterus.

From craniotomy there should be in favorable cases no greater mortality than from forceps deliveries. The operation is seldom performed until after the forceps has been tried severely, and the patient been bruised and often infected. In view of the very low death rate of other methods, it should not be the primary selection of method in the hands of experienced and properly prepared obstetricians; but it may often be the most expedient method for the general practitioner, in whose hands most labors occur outside of hospitals.

Given a patient not in labor but requiring induced premature labor, symphysiotomy, or Cæsarean section to secure delivery of a living child, and an obstetrician of equal experience in each method and regularly engaged in doing abdominal surgery, due regard being given to both mother and child, in cases of medium contraction not permitting forceps delivery, symphysiotomy should be selected. With more marked contraction the Sänger Cæsarean section should be preferred. Cases of severe manipulation, with the child in good condition, with probable infection of the uterus present, call for symphysiotomy in preference to the Porro operation. Symphysiotomy is not affected by infection if the writer's subcutaneous method is employed; Cæsarean section is markedly affected. If the child's condition renders delivery alive very problematical, further effort with forceps and then craniotomy may be best. The *a priori* argument in cases complicated by tumors and local diseases is in favor of Cæsarean section. Induced labor is generally decided upon by the patient.

If the physician is not accustomed to abdominal surgery, he should select symphysiotomy in preference to Cæsarean section. If he is not accustomed to any surgical work, he should choose induced premature labor, or perform craniotomy, if he must deliver the patient himself.

The Choice of Method in Cæsarean Section.—The Porro method is not only indicated but required in all cases of suspected existing infection of the uterus. This is the situation in cases in which extensive efforts have been made by others to secure delivery by use of the forceps or by version; when the amnion has been ruptured for hours and most of the fluid drained away; when the cervix is swollen and œdematous, the vagina hot and dry, and the vulva swollen; also when tumors and pathological changes are present in the soft parts which interfere with passage of the fœtus; in rupture of the uterus at sites difficult to suture, or when it seems safer to do a hysterectomy than to suture a jagged wound at any site. It may be indicated in very exhausted conditions of the uterus with hemorrhage present or threatening. It is indicated in certain conditions of the very rare occurrence of combined intra- and extra-uterine pregnancy. It is not indicated as a means of preventing future pregnancy, unless the operator is perfectly satisfied that he can perform it with the same degree of safety that he could a Sänger section.

To a physician of comparative inexperience in abdominal operations the Sänger Cæsarean section is probably an easier and safer method than the Porro hysterectomy.

Edward A. Ayers.

CAFFEINE.—*Theine.* $C_8H_{10}N_4O_2,H_2O$. "A feeble basic, proximate principle, obtained from the dried leaves of *Thea sinensis*, Linn. (nat. ord. *Ternstrœmiaceæ*), or from the dried seeds of *Coffea arabica*, Linn. (nat. ord. *Rubiaceæ*), and found also in other plants" (U. S. P.).

"An alkaloid usually obtained from the dried leaves of *Camellia Thea*, Link, or the dried seeds of *Coffea arabica* Linn." (B. P.).

It occurs in fleecy masses of long, flexible, white crystals, permanent on exposure, of a silky lustre, having a bitter taste, and without odor. Soluble in eighty parts of cold water, in two parts of boiling water, and in thirty-three parts of alcohol. It is neutral to test paper. When ignited it is consumed without residue. A notable feature is the unusually large proportion of nitrogen that it contains.

The only official salt is the citrate, which is very unstable and rapidly deteriorates, the alkaloid separating and remaining uncombined. When mixed with three parts of water, the citrate forms a thick liquid; when more water is gradually added the caffeine is precipitated, but redissolves and forms a clear solution when twenty-four parts of water are added. It is a white powder, without odor; it has a bitter taste and an acid reaction. When burned it chars and leaves a slight ash. It is soluble in thirty-two parts of water.

An effervescing citrate is official in the United States Pharmacopœia and the British Pharmacopœia. The former contains one per cent. of caffeine, that of the British Pharmacopœia contains nearly four per cent.

Caffeine is the characteristic alkaloid of coffee and tea. It was discovered and first prepared, in an impure condition, from coffee, by Runge, in 1820, and shortly after, in a state of greater purity, by Pelletier and Robiquet, and other chemists. In 1827 Oudry separated an alkaloid from tea, which he named *theine*. This, in 1838, was proved by Mulder and C. Jobst to be the same as Runge's caffeine. In 1840 Martius discovered *guaranine* in guarana, and afterward the same observer, and others, proved its identity with the alkaloid of coffee. The same substance was also found, in 1843, by Stenhouse, in the leaves of maté or Paraguay tea, and in 1865, by D. Daniel and by J. Attfield, in the kola nuts (*Sterculia*) of Africa. In all these products it appears, moreover, to be the most important ingredient. As no two of these plants are nearly related to each other, or are even in the same order, caffeine may yet be found to be as widely distributed in the vegetable kingdom as berberine or buxine. It is an interesting fact that all the above substances have been used from a remote time by communities which could have had no communication with each other, for exactly the same purpose, viz., as a stimulating and comforting addition to their daily food; tea by the Chinese, coffee by the Arabs, the kola nuts by the Africans, and maté and guarana by different tribes of South America.

For commercial purposes caffeine is prepared exclusively from tea and coffee; the poorer sorts, that is "tea dust" and damaged and inferior grades of either tea or coffee, being used. As the price of both these articles does not depend at all upon their alkaloidal strength, but only upon their appearance and flavor, the cheaper grades often contain considerably more caffeine than the more expensive ones, and, price apart, are better for this purpose.

The percentage of the alkaloid in the several plants varies greatly. It is estimated that tea contains from one to four per cent.; coffee, one to three; maté, one to two; and guarana about five per cent.

Caffeine acts upon the cerebral, medullary, and spinal centres, primarily as a stimulant and later as a depressant. Its action is also directed to the muscular tissue, improving its tone and contractile power, until ultimately it merges into the general depression.

In small doses, from one to three grains, it produces a sense of well-being, and a feeling of increased strength and vigor. The cerebral functions become more active, the respirations are deeper, the heart beats more forcibly, and the arterial tension is increased. The heart at first participates in the general stimulation, and there is an increase in its frequency and a more rapid pulse. This, however, is transitory, as the inhibitory centres are soon influenced by the stimulation and produce a slowing of the heart's action, which, with the more forcible contraction of the muscular walls, constitutes its most desirable effect. The urine is increased, both the quantity and the contained solids being greater. Tissue change is accelerated, and the body temperature rises. This beneficial action continues for some days, after which the continued use is liable to give rise to signs of cardiac irritation and excessive vascular tension. There may be a rapid, hard pulse, a feeling of constriction in the chest, dyspnœa, and labored action of the heart.

In larger doses, from gr. v. to gr. viij. or x., the symptoms of over-stimulation are developed early, and if the drug is continued, the depression follows rapidly and may become very marked. In addition to the cardiac and respiratory distress, there are insomnia, vertigo, tinnitus aurium, flashes of light, mental distress, and delirium. As the depressant action replaces the stimulation, the inhibitory control of the heart is lost and there follows a rapid, feeble heart beat, which gradually increases until contractions cease. The respirations also become shallow, and there follows a condition of asphyxia and collapse, death being due to respiratory failure. Caffeine is an irritant to the gastric mucous membrane, and its continued use produces heat and burning at the epigastrium, with nausea, which may terminate in pain and severe irritation of the stomach and intestines.

Caffeine was formerly considered only as a cardiac stimulant and administered freely, with very little thought of any subsequent depression. Later experience has shown that this secondary action is of the greatest importance, and although often unrecognized, it is a frequent cause of serious depression, and possibly of death. Cases of acute poisoning are rare, and in healthy adults the quantity necessary to cause death would be very great, but in diseased states its action is much accentuated. In valvular disease and in conditions in which the heart is being overtaxed, even ordinary doses may be attended by very serious consequences. The danger is not only from large doses, but also from the continued use of moderate doses.

Attention has also been directed to an unfavorable condition that may arise during its administration, prior to any depressant action. This is an over-stimulation and irritation of the cardiac ganglia that may terminate in a spasmodic contraction of the heart and death. The following are given as instances of death from this cause. In a case of pneumonia, death occurred suddenly, when the patient was taking caffeine, three grains three times a day. A woman with chronic parenchymatous nephritis, anasarca, and double pleural effusion had taken small doses for some time previous to a sudden fatal syncope. In a third case death took place suddenly, the patient being a young girl who had acquired the habit of taking frequent doses of gr. iv. or v. In all these cases a postmortem examination was made and the heart found firmly contracted, death being due to a condition described as a "tetanus of the heart muscle."

Caffeine is employed as a cardiac and general stimulant, as a diuretic, and for the relief of headaches and neuralgia pains. Its value as a stimulant is well recognized, and its rapid action makes it of value in cases of sudden weakness and threatened syncope. In addition to its value in threatened heart failure, it is most useful in chronic valvular disease, to counteract a failing compensation. It, however, must always be given cautiously when the heart is feeble and dilated, or in any form of heart disease in which the walls are diseased. In arteriosclerosis it is also contraindicated, as it adds to the already high arterial tension.

The diuretic action of caffeine is always to be depended upon, and is that for which it proves of greatest service. It is in a measure due to the increased arterial pressure, but caffeine also exercises a direct action upon the renal secreting tissue. It is particularly indicated in the dropsy of cardiac disease, and resembles digitalis in its action. It acts more rapidly, but has not the same power to strengthen the heart and increase the blood pressure. For this reason its effects are often better when preceded by digitalis, or when the two are combined. When there is kidney disease it must be given with care, as the stimulation of the renal tissue may aggravate the local trouble. In dropsy due to hepatic disease, its action is very uncertain.

Caffeine has not proved of much value in the treatment of headaches. In many forms of neuralgia and migraine, in the debilitated and nervous, it may prove of service, but this is due to the improved tone of the nervous system, and not to any anodyne or analgesic property

In administering caffeine, the citrate is frequently selected on account of its greater solubility. When used it should have been carefully preserved, and it must be given in powder, or dissolved immediately before use, as it rapidly decomposes when in solution. The citrate is one-half the strength of the pure alkaloid, and gr. x.–xv. during the day is the average dose. When an immediate effect is required, it may be administered subcutaneously. A product that is much employed is the double salt of caffeine, with soda and salicylic, benzoic, or cinnamic acid. It is very soluble and unirritating, and furnishes the best solution for hypodermic use. It is about one-half the strength of the citrate. These salts were proposed as the best means of obtaining the diuretic action of caffeine, but later experiments seem to indicate that these combinations are not so serviceable as were expected. It has been found that the presence of soda and salicylic acid has a tendency to reduce blood pressure and to lessen the secretion of urine. This, it is thought, must influence unfavorably the caffeine when it is thus combined with other drugs. The compound salts, however, are very highly thought of and are becoming more frequently employed. The following formulæ for their preparation are official in the Paris Codex: (1) Caffeine, 4; sodium salicylate, 3; distilled water to 10 parts. (2) Caffeine, 2.5; sodium benzoate, 3; distilled water to 10 parts.

Beaumont Small.

CAISSON DISEASE.—This term has inappropriately been applied to the whole group of accidents which result from working in compressed air. As Snell aptly says, the name of a disease should indicate some characteristic symptom or some etiological factor. This is manifestly not the case in the present instance. The caisson itself has nothing whatever to do with causing the disease which bears its name. As indicated above, *compressed air* is the causative factor and should be the term substituted for *caisson*. *Compressed air illness*, then, will include all this class of accidents under discussion.

In laying the foundations of bridge piers or abutments under water, various means are resorted to for displacing the water and building a solid basis; one of these methods is by means of caissons. The caisson, or caissoon, is made of different patterns, but the one with which we have to do in the study of caisson disease is like a large inverted cylindrical box supplied with apparatus for condensing air to such a degree as to expel and keep out the water, thus enabling men to work in it. When the in-rushing water cannot be removed by pumping, other means must be resorted to. The method now in vogue is the use of an air-tight diaphragm at some point in the cylinder. The workmen and material used are passed through a small space or ante-room called the "air lock," with which the diaphragm is provided. This chamber is furnished with two air-tight doors, an inner and an outer, both of which open toward the compressed air. When the men have entered this air lock, the outer door is closed and compressed air is gradually admitted by means of cocks until the air in the lock is of the same density as that in the caisson; then the door of admission to the latter is opened. In returning, the process is reversed, the air in the lock being gradually rarefied.

If the fact be borne in mind that the body has about sixteen square feet of surface, and that ordinary atmospheric pressure is about fifteen pounds to the square inch of surface, it may readily be understood that an increase of atmospheric pressure will have some effect on the conditions of the interior of the body. The blood is driven, by reason of this external pressure, from the surface into the bones, cranium, spinal canal, and other parts of the body. If this change of location of the blood be effected too rapidly, or if too much force be applied, the results may be dangerous.

A number of factors must be considered as entering into the production of this disease, in the enumeration of which Snell's order has been followed. Primarily, there is the high atmospheric pressure. As would naturally be expected, the extent of the illness varies in proportion to the degree of this pressure. The length of time of exposure is also an important factor, the longer the period the more severe the symptoms. Ventilation has such an important influence on the degree of this illness that Snell has formulated the following law: "The amount of illness varies inversely with the amount of fresh air supplied to the compressed air chamber." Too rapid decompression should be avoided. Minor etiological factors are: fulness of habit, age, organic disease, alcoholism, severe exertion after decompression, and unfamiliarity with the work, all of which, with the exception of organic disease, militate unfavorably for the patient. As those with organic disease are generally rejected, observations concerning its effect on this disease are not at hand. One sufferer with emphysema, who came under the notice of Snell, was always in better health when working in compressed air. Temperature and hygrometric conditions of the air lock seem to bear no relation to the illness.

In an essay on "The Effects of High Atmospheric Pressure, Including the Caisson Disease," Dr. Andrew H. Smith, of New York, describes the symptoms induced by entering highly compressed air. These, with a few additions, are: (1) Ringing in the ears and impairment of hearing; (2) increased frequency of respiration; (3) increase in the pulse rate to 120, with subsequent fall to the normal; the pulse is reduced in volume, and there are pallor and sallowness of the skin; (4) the temperature of the body, an hour and a half after entering the caisson, is elevated about one degree, but when the atmosphere within the caisson is warmer than the external air, the body heat may rise as high as 101° F.; (5) the skin is covered with perspiration, but this is because of the saturation of the surrounding atmosphere, and not from any increase in the amount of the secretion; (6) increase of appetite; (7) dysphagia at times; (8) fatigue; (9) increase of urine of about normal specific gravity (probably because of diminished evaporation from the skin). No albumin is present.

The pathological effects mentioned are: (1) Rupture of the drum membrane and inflammation of the middle ear; (2) epistaxis or hæmoptysis; (3) itching of the skin; (4) neuralgic pains, which may come gradually or suddenly, in the extremities or in any part of the body; when in the lower extremities, they are commonly known as "bends"; (5) epigastric pain and vomiting; (6) paralysis, both sensory and motor, most frequently of the lower limbs, but, notwithstanding the paralysis of sensation, the pains continue; (7) the cerebral symptoms are: headache, dizziness, double vision, incoherence of speech, and sometimes unconsciousness. These symptoms are usually temporary. "Death occurs only in cases which are severe from the first, and are marked by symptoms of serous or sanguineous effusion about the brain or cord." "The constant lesion in fatal cases of caisson disease is congestion of the brain or spinal cord." "It is the *removal* of the pressure, and not the pressure itself, that is the immediate cause of the seizure," which occurs usually at the time when the victims are coming from under the pressure, or even some hours subsequently. The blood is driven by the atmospheric pressure from the surface into the bones and bony spaces, skull, and spinal canal, the vessels of which parts become dilated, and when the external pressure is removed, they do not readily contract to their normal size. Lloyd believes the lesion to be destructive or necrotic, due to the deprivation of blood. Congestion of various organs has been observed. Areas of softening in the brain and cord have been described.

According to Lloyd, the exact pathology of this disease is not perfectly clear, and, indeed, as Smith believes, it may vary in different cases. Several theories have been advanced: congestion followed by blood stasis; lowered vascular tone; revulsive anæmia; extreme destruction of body tissues not followed by proper elimination; excess of oxygen.

Much can be done to prevent caisson disease. Due precautions should be taken for the thorough ventilation of the air chamber, as this is one of the most important prophylactic measures. Care and experience will often admit of the engineering work being carried on at a much higher level than would ordinarily be thought possible. The length of time which the workman spends in the compressed air should be intelligently regulated—much depending on the degree of pressure. The "locking-out" process must be attended to most carefully. The workmen ought to be taught how to care for themselves. The following points should be emphasized: the method of inflating the ears; hygienic precautions while in the chamber; rest, and a warm drink, preferably coffee or beef tea, after decompression, together with a change to warm clothing. The chamber should be lighted by electricity.

As to curative treatment, the remedy that Smith proposes for this condition is ergot, with morphine as required to relieve pain. Recompression affords the greatest relief to the pains if the patient is seen soon after their onset. Liniments are approved by some, but discarded by others. Bandaging is often efficacious to relieve pains in the extremities. Salicylate of soda has been used. Inhalation of oxygen has been suggested in view of the theory of retained carbonic acid gas. Electricity has not met with much success. Complications must receive the ordinary treatment indicated in such cases. When vertigo is obstinate and persistent, tonics seem to afford the greatest relief.

Charles E. Hackley.
Emma E. Walker.

CAJEPUT, OIL OF.—*Oleum Cajeputi.* A volatile oil distilled from the leaves of *Cajeputa Leucadendron* (L.) Rusby (fam. *Myrtaceæ*). This species is a rather small, fragrant tree, with irregularly growing slender branches, and a thick, soft, exfoliating bark. The leaves are bright, smooth, narrow, entire, pointed at each end, parallel nerved, and often oblique or curved; they are twisted upon their petioles so as to stand with vertical surfaces, like phyllodia. The tree is a native of numerous islands in the Indian archipelago, especially of Borneo, Celebes, and Amboyna. It is also extensively found, if a broad view is taken of the species, in Australia and on the mainland of Asia. Most of the oil is obtained from Celebes, and exported by way of Javan or Indian ports.

Oil of cajeput is extracted on the spot from the fresh leaves, which are first softened by maceration in water, and then subjected to distillation in rude copper stills. It is filled into once-used wine and beer or other European bottles for exportation. It was first introduced into Europe in the early part of the eighteenth century.

It is a pale green, transparent, mobile fluid, with a fragrant mint or camphor-like odor, and bitterish aromatic taste. It has the usual physical properties of the essential oils. It is very similar to its near relative, oil of eucalyptus, containing the same constituent, cineol, along with terpineol and other bodies. Specific gravity of the oil, about 0.926. The green tint is generally ascribed to some compound of copper received from the still, or introduced into the oil intentionally. The color may be separated by several methods of rectification, and the oil obtained clear and white.

Action and Use.—Cajeput has the stimulating properties of camphor and the essential oils in general, and stands between the most irritant of them, like oil of turpentine, and the milder mint oils. It is more extensively used in the Indies and Eastern islands than here—in some places being given for nearly everything, but is particularly popular for colics, diarrhœas, and even cholera, as well as for chronic rheumatism, chronic vesical catarrh, etc. Here it is not often given internally, but has no doubt some value in non-inflammatory intestinal disturbances, where an aromatic stimulant and antispasmodic is needed, being in these cases very much like camphor, and like this may be very suitably combined with opium. Externally it is a mild rubefacient, and a good ingredient for stimulating liniments in chronic rheumatism, old sprains, etc.; it may be also useful for psoriasis, scaly eczema, etc., and is a fairly efficient parasiticide. As a stimulant diuretic in chronic vesical catarrh it is as good as most others of its class. Cajeput is the basis of numerous toothache and earache drops. It is often adulterated. Dose, from 1 to 5 dgm. (♏ij. to viij.) dissolved in spirit, suspended in mucilage or syrup, or on a lump of sugar. There are twenty or thirty drops to the gram.

W. P. Bolles.

CALABAR BEAN. — Physostigma. *Ordeal Bean, Chop-nut.* "The seed of *Physostigma venenosum* Balfour (fam. *Leguminosæ*)" (U. S. P.). This plant is a large, climbing, perennial vine, with trifolioiate leaves and the general appearance of an enormous bean vine. The stem is woody below and often as large as the wrist. The showy purple flowers are nearly as large as those of the sweet-pea, and hang in loose racemes. The large pods contain two or three seeds each. The "beans" are very hard, oblong, slightly curved or kidney-shaped, from 2 to 3 cm. in length, and about 1.5 cm. broad (.75 to 1.25 in., by .5 in.), and covered with a roughish but shining chocolate-brown or brownish-red testa. A broad, shallow, black groove or furrow extends along the convex border and around one end of the seed; it contains the raphe. The kernel is exalbuminous and consists mostly of the two large, white, brittle cotyledons, whose faces are concave and enclose an air space which enables the entire seeds to float upon water, although when broken the fragments are denser than water. The taste and odor of the seeds are simply bean-like, and give no suggestion of the deadly poison which they contain.

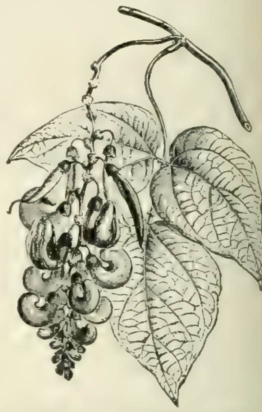

Fig. 1068.—Calabar Bean Vine; Flowering Branch, Reduced. (Baillon.)

The plant grows about the mouths of the Old Calabar and Niger rivers in tropical West Africa. It has been transplanted to India, Brazil, and other places, where it flourishes. Physostigma is an ingredient of the poisonous mixture which persons accused of witchcraft or crime are compelled by the savage chiefs of these African tribes to take as an ordeal or punishment. The draught is usually rapidly fatal, unless vomiting occurs. It was first known in England about 1840 as a curiosity and poison, but not much employed in medicine until Fraser, of Edinburgh, about 1863, discovered its specific power of contracting the pupil, since when it has been in rather frequent use by oculists and in occasional use in internal medicine. Besides forty-eight per cent. of starch and about twenty of albuminoid matters, with a little oil and gum (substances which are contained as well in the common bean, and which are entirely inert), the drug in question contains three alkaloids, with *physosterin*, a fatty or cholesterin-like substance, which occurs in the Calabar bean in common with other leguminous seeds, and which is inert.

Fig. 1069. Calabar Bean, Two-Fifths Natural Size.

Physostigmine or *eserine* is the principal alkaloid. *Calabarine* is apparently a derivative of the former, while eseridine can be converted into physostigmine. The action of physostigmine dominates that of the drug, especially as that of eseridine is very similar. Calabarine acts antagonistically to the others, but is in such small amount as not greatly to modify the drug's action. The action of Calabar bean will therefore be discussed under *Physostigmine*.

Except in the form of the alkaloid, calabar bean is but little used. It has been rather thoroughly experimented with for its depressing action upon the nerve centres in various diseases involving central excitability, and especially in tetanus; but the results cannot be regarded as encouraging. Some benefit has resulted from its use in checking the paralysis of insanity, and it often does good as an intestinal laxative. We have an official extract, the dose of which is .006 to .03 gm. (gr. $\frac{1}{10}$ to $\frac{1}{2}$), and a fifteen-per-cent. tincture, the dose of which is .6 to 2 c.c. (♏x. to xxx.).

Physostigmine or *Eserine* ($C_{15}H_{20}N_3O_2$). The chemistry of this alkaloid, and its relations to the bodies associated with it, are but imperfectly known. Formerly, the two names were believed to represent two alkaloids, but it was subsequently ascertained that one was merely an impure form of the other. It is almost always used in the form of its salts. The pure alkaloid occurs in the form of colorless crystals which are soluble in both alcohol and water, slowly in the latter. They are very hygroscopic and quickly lose their characters if exposed to dampness or light. Of the numerous salts, the most important are the hydrochloride, sulphate, and salicylate, the two last being official. The sulphate $(C_{15}H_{21}N_3O_2)_2$,-H_2SO_4, a white or whitish crystalline powder, which is the salt most used, is very soluble in both water and alcohol. The salicylate, $C_{15}H_{21}N_3O_2,C_7H_6O_3$, in white crystals, is less soluble, namely, in one hundred and fifty parts of water or twelve parts of alcohol. The hydrochloride, $C_{15}H_{20}N_3O_2HCl$, is soluble in water.

Action.—The physiological action of eserine is powerful and characteristic, and has been very extensively studied. Except in large poisonous doses, its chief action is upon the secretion and involuntary muscular movements, through the cells and fibres, or their nerve endings, or both. The secretions of the entire alimentary system, excepting perhaps the bile, are markedly increased, in which particular a close similarity to pilocarpine has been noted. The perspiration and tears share in this increase. At the same time, the activity of the gastric and intestinal muscles is greatly augmented also. The effect upon the stomach may be such as to cause vomiting, especially by large doses, poisoning being thus avoided. More or less nausea is frequent. If vomiting does not occur, then purgation may, owing to a similar effect upon the intestinal muscles, combined with the increased secretion. Looseness of the bowels is an ordinary symptom. Uterine contractions may be induced. Coincident with these effects, and evidently of the same general nature, is the contraction of the pupil and ciliary muscle. In all these directions, the drug is directly antagonistic to atropine, and one drug can be used to counteract the other, to a great extent. Strychnine, while directly antagonistic to physostigmine in its central effects, strangely enough produces, through the spinal centres, many symptoms similar to those produced by the latter through peripheral action. In the voluntary muscular system, there is increased irritability of the fibre, and apparently stimulation of the nerve endings also. This produces muscular twitchings among the most prominent of the early symptoms of poisoning. It is apparently due to bronchial spasm that respiration is slightly interfered with. This interference acts as a respiratory stimulant, and the respirations are early increased both in number and force. At the same time there is a marked rise of blood pressure, though this is quite irregular. The heart is continuously and powerfully slowed from the start, due apparently to direct action upon it, but the beat is strong. There is the widest disagreement as to whether primary central stimulation occurs and is partly responsible for these symptoms. Whatever may be the primary central effect, depression of the motor centres is early and powerful. If the dose has been large, and is not vomited, paralysis may be very sudden. There may then be almost no preliminary symptoms, or the muscular twitchings may amount almost to convulsions. With increasing cardiac slowness, weakness and reduced blood pressure supervene; but this effect is not so marked as respiratory depression, which is the immediate cause of death.

Uses.—Physostigmine salts have been used, as already stated, for the same purposes as Calabar bean, in doses of .001 to .003 gm. (gr. $\frac{1}{60}$ to $\frac{1}{20}$). Their chief use, however, is for instillation into the eye, in solution of one-per-cent. strength or weaker. The effect is to produce, at the end of a half-hour, a very powerful contraction of the pupil, which lasts for ten or twelve hours, and markedly to decrease intraocular tension, after a brief increase. It thus becomes of service in overcoming the interference with vision induced by the use of atropine. Efforts have been made, with some success, to destroy iritic adhesions by its use.

Pseudo-physostigmine is an alkaloid having apparently the same composition and properties; it is derived from cali-nuts or false Calabar beans, the botanical origin of which is doubtful.

Henry H. Rusby.

CALAMUS. SWEETFLAG.—The rhizome of *Acorus Calamus* L. (fam. *Araceæ*). An endogenous perennial with a thick, fleshy, long and branched horizontal rootstock, and a few very long and narrow (.5 to 1 m.) linear equitant leaves. The flowering scape is also long and flattened, like one of the leaves, and bears at its apex a straight, solid, fleshy, cylindrical spadix from 5 to 10 cm. long. Flowers perfect, small, crowded. A long, leaf-like bract or "spathe" (Bentley and Trimen) arises at the junction of the spadix and scape, and, proceeding in a straight line, looks like a continuation of the scape, while the really terminal spadix is diverted to an angle with the axis, and appears to be lateral. Sweetflag is indigenous in parts of Asia, as Asia Minor, India, etc., and in some parts of Europe and North America, but has been so extensively spread and naturalized by human intervention that it is found in nearly the whole north temperate zone. It grows either in the water or in swampy and shady places, and is very variable in size.

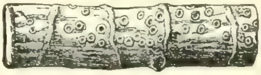

FIG. 1070.—Rhizoma of Acorus Calamus, Showing Cicatrices of Adventitious Roots. (Baillon.)

All parts of the plant are slightly aromatic, the leaves least so, but for medicinal use the rhizome only is employed. It should be gathered in the autumn or spring, washed, cleaned, and dried. In Germany it is generally peeled or scraped before drying; but while the appearance is improved by this process, the strength and quality are deteriorated, and this is not authorized by our

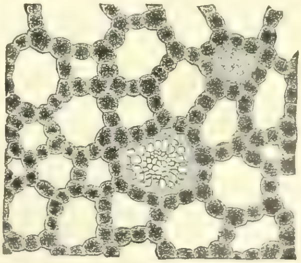

FIG. 1071.—Transverse Section of the Same. (Baillon.)

Pharmacopœia. Although it grows in great abundance in the swamps of the United States, a large portion of what we use is imported from Europe or Southern Russia.

Calamus comes in pieces of from 10 to 30 cm. or more in length, by 1 or 2 cm. in thickness (from 4 to 12 in. × ½ in.); it is shrivelled and lightly flattened, marked by frequent and very distinct rings and remains of leaf scales, and below is covered with the circular scars of the roots. It is pale or reddish brown externally, white and spongy within. Its texture is very light, being traversed by large air spaces separated by only a single row of cells. A cross-section shows these as large holes, and the walls as a lace-like reticulation, varied with occasional woody bundles (see Fig. 1071). The oil cells are like those of the general parenchyma, but larger, and are generally situated in the angles formed by the confluence of three or four of the partitions, as shown in the section.

The principal constituent is the *oil*, of which it contains two or three per cent., a yellowish or brownish, very fragrant liquid of specific gravity 0.9. It also contains the glucoside *acorin*, which is a soft, resinous substance, with a bitter, aromatic taste, resin, starch, tannin, gum, and a minute amount of the alkaloid *calamine*.

Calamus is a pleasant tonic, aromatic-bitter, applicable to all the purposes for which such remedies are used. Dose, from 2 to 4 gm.; of the oil, from gtt. x. to gtt. xv.

No other species of Acorus has any special value.

W. P. Bolles.

CALCIFICATION.—(*Calx*, lime; *fio*, to become.) Conversion of tissue into chalky matter by the deposition of lime salts. It is not unusual for solid particles, either crystalline or amorphous, to be deposited in the tissues throughout the body, and when the area so affected is large enough to be perceptible, it is said to be calcified or petrified. Chemically, calcareous matter consists chiefly of calcic and magnesic phosphates and carbonates. Calcification should be distinguished from ossification; for in the former there is no formation of bone, but merely a deposit of calcareous matter. Under the microscope the tiny particles look dark and opaque by transmitted light, though when in masses they are glistening. Not infrequently they look like fat, but are soluble in dilute mineral acid, and often give off gas bubbles from the decomposition of earthy carbonates. These tissues show a change in staining properties, hæmatoxylin, *e.g.*, producing a dingy bluish-violet color. This applies to the carbonates and phosphates of lime, not to the oxalate. Calcification takes place in various tissues, both in the cells and in the intercellular substance; but the type most apt to be affected is connective tissue which has already degenerated to the hyaline stage and from which the nuclei have entirely or almost disappeared. Dying tissue seems to have a kind of attraction for the lime salts in solution in the body, entering into close combination with them. However, the process does take place at times in tissues which have undergone no apparent change, especially in old age when the lime salts are undergoing more rapid absorption. There is a curious affection called *myositis ossificans progressiva*, in the course of which some of the muscular fibres undergo calcification. Again, the myocardium may be affected by the same type of degeneration, and the heart-muscle fibres become hardened by lime salts. A well-known example of calcification is seen in the walls of arteries where it follows fatty and atheromatous degeneration and sclerosis. "Calcification of the intima is a common terminal process of arterio-sclerosis" (Osler). The coats affected are the intima and the media. When the latter is involved there occurs what is known as annular calcification, in which the artery—most commonly medium-sized—develops into a rigid tube. The arteries most apt to be attacked by calcareous degeneration are the aorta and its larger branches, the arteries of the extremities, of the brain, of the heart, and of the spleen, as well as disused arteries, such as those of a stump and of the senile uterus. Veins are sometimes affected, though rarely, the most common instance being the walls of the varicose veins. The valves and orifices of the heart are a frequent seat of this degeneration. Other tissues undergoing this change at times are fibrous or fibro-serous membranes, *e.g.*, the pericardium, walls of hollow organs, the dura mater, pia mater, and choroid plexuses, when it is known as "brain sand." Cartilage, nerves, and various glands, organs, and tumors are at times the susceptible part. Calcification may occur in tubercle. The cheesy nodules in the crypts of hypertrophied tonsils sometimes calcify. Calcification of areas of tuberculous lungs results oftentimes in "lung stones" which are afterward expectorated (Osler). This form of degeneration is sometimes connected with other morbid processes. These lime-salt deposits may occur in two general ways. They may infiltrate the tissue of an organ which continues to retain its original relation to surrounding parts (*e.g.*, calcification of the membrana tympani), or they may incrust parts of tissue which are separated from their normal surroundings, or foreign bodies which have entered the body previously. In the first instance there results calcification; in the second, concretions or calculi. On the other hand, concretions at first free from surrounding tissue may later become firmly attached, or calcified tissue may separate from its surroundings and become free.

The *Etiology* of this degeneration is generally traceable to a lowered vitality of the tissues, which may depend on various conditions, such as old age or insufficient blood supply with slow circulation. But it is not confined to old age, as it is exceptionally observed in infancy, as well as in adolescence and middle age. In the latter period, it is due to various cachexiæ, such as gouty or syphilitic, while it is always an accompaniment of chronic kidney disease. The precedence of other forms of degeneration has been noted. Sometimes there is an excess of lime salts in the blood. In certain instances the tissues are unable to assimilate the fluid in which the salts are in solution. In other cases the carbonic acid which holds the salts in solution escapes, thus causing the deposit. Certain diseases of bone in which its salts are rapidly absorbed, or in which there is obstruction to renal elimination, are often associated with calcification. In the latter case the kidneys are particularly affected. The kidney epithelium is especially susceptible in corrosive sublimate, bismuth, or aloin poisoning (Ziegler).

The process is attended many times by alarming *Symptoms*, the nature of which depends upon the location and extent of the trouble, *e.g.*, apoplexy, angina pectoris, aneurism, senile gangrene of the extremities, and various forms of cardiac disease. But the symptoms due to simple degeneration of arteries are often very indefinite. Calcification is at times the sign of cessation of some morbid process, as, *e.g.*, in tuberculosis, where the diseased foci may be rendered inert by the development of this degeneration.

The *Diagnosis* of this condition may sometimes be made by touch, as in the case of a peripheral artery. Calcareous particles may be discharged from the body; or the presence of the degeneration must be inferred from the symptoms caused by it.

Treatment of this condition, particularly when it is found to be present in the walls of the blood-vessels, consists in forbidding excitement or excesses of all kinds, both bodily and mental. *Emma E. Walker.*

CALCIUM.—1. General Medicinal Properties of Compounds of Calcium.—In the group of metallic elements represented by the metals of the alkalies and of the earths, calcium is distinguished, in its relations with the animal economy, by its comparative inertness. The medicinal characteristics of lime preparations as a class are lowness of diffusion power, and hence difficulty of absorption, slight local tendency to repress secretion, and slight constitutional tendency to oppose degenerative processes in tissues. Individually, the calcic compounds differ greatly in their properties, and thus arise many individual therapeutic applications, to be noted under the several preparations.

2 THE COMPOUNDS OF CALCIUM USED IN MEDICINE.—The compounds of calcium that enter into the pharmacopœial preparations containing the metal are the *monoxide, hydroxide, carbonate, phosphate, sulphate, hypophosphite, chloride, bromide, sulphide* (in the preparation *sulphurated lime*), and the compounds, whatever they be, that form the substance called *chlorinated lime*. In the present article will be discussed only the *monoxide, hydroxide, carbonate, phosphate,* and *sulphate*. For the other compounds above cited, see, respectively, *Hypophosphites, Chlorides, Bromides, Sulphides* and *Chlorine*.

Calcium Monoxide: CaO.—Calcium monoxide in the form of the ordinary "lime," or "quicklime" of commerce, is official under the simple title *Calx*, Lime. It is officially described as "hard, white or grayish-white masses, which, in contact with air, gradually attract moisture and carbon dioxide, and fall to a white powder; odorless, of a sharp, caustic taste. Soluble in about seven hundred and fifty parts of water at 15° C. (59° F.), and in about thirteen hundred parts of boiling water; insoluble in alcohol. Soluble in diluted acetic, hydrochloric, or nitric acid. When sprinkled with about half its weight of water, lime becomes heated, and is gradually converted into a white powder (calcium hydrate or slaked lime). When this is mixed with about three or four parts of water, it forms a uniform smooth magma (milk of lime). Even at the highest degrees of heat lime remains unaltered and does not fuse. Its aqueous solution gives an intensely alkaline reaction with litmus paper" (U. S. P.). Because of the strong affinity of lime for water, it should be kept in tightly closed vessels in a dry place. Lime is obtained from some of the varieties of native calcium carbonates, or from white marble or oyster shells, by calcining.

Physiologically the importance of quicklime lies in the fact that because of its intense affinity for water it is caustic. To a moist surface it is powerfully escharotic, and since the product of the caustic action (slaked lime) is a nearly insoluble solid, the action is non-spreading.

In practice, quicklime is rarely used by the surgeon, except in the form of the composite preparation, *potassa with lime* (Vienna caustic), for whose description see under *Potassium*.

Calcium Hydroxide: $Ca(OH)_2$.—Calcium hydroxide is the familiar substance, *slaked lime*, which forms in the shape of a white powder as the product of the chemical reaction between lime and water. The reaction is attended by the development of a high degree of heat. Slaked lime is not official in the United States Pharmacopœia under any distinctive title, but the preparations into whose composition it enters are defined as preparations of lime simply. Slaked lime is a soft, white, bulky powder, of a mawkish, alkaline taste, and having the solubilities detailed above in the pharmacopœial description of lime. Although a powerful free base, it is not caustic to living tissue, because of its difficult solubility in water. Combining as it does, therefore, the qualities of harmlessness and high alkalinity, it is valuable as an antidote—so far as antidotes go—in poisoning by acids. Especially is it to be selected in cases of poisoning by oxalic or sulphuric acid, because of the great insolubility of the salts it makes with these several acids. For medicinal purposes, proper, slaked lime is used in the valuable pharmacopœial preparation commonly known as *lime water*, but officially entitled *Liquor Calcis*, Solution of Lime. This is simply a saturated aqueous solution of slaked lime, easily made by any one by stirring freshly slaked lime into water—fairly pure water free from salts—in any proportion greater than 1 to 750. The vessel containing the resulting solution is to be kept tightly stoppered, with the excess of undissolved lime retained. After the settling of the undissolved portion, the clear, supernatant liquor may be drawn off in small quantities, for use, by decanting or siphoning. The object of having an excess of lime lies in the fact that lime water has a great affinity for carbon dioxide, absorbing this gas from the atmosphere and forming with it the insoluble calcium carbonate. By such reaction the lime of lime water gradually becomes exhausted, but by the device of keeping in the containing vessel an excess of lime, the water of the solution recharges itself therefrom as fast as it loses strength by carbonating, and the solution of lime is thus maintained steadily at saturation. Lime water is "a saturated, aqueous solution of calcium hydrate. . . . The percentage of calcium hydrate varies with the temperature, being somewhat over 0.17 per cent. at 15° C. (59° F.), and diminishing as the temperature rises" (U. S. P.). Although clear when first made, lime water, upon keeping, is certain to become turbid from absorption of carbon dioxide from the atmosphere, and the formation thereby of calcium carbonate. If, however, there be, as above advised, an excess of lime in the bottle, the turbidity does not mean loss of strength, and a sample so affected is perfectly good for medicinal purposes. Lime water is incompatible with alkaline carbonates, sulphates, borates, salts of ammonia and the metals, acids and acidulous salts, and astringent vegetable decoctions or infusions.

Lime water is, of course, alkaline, and at the same time is, physiologically, locally bland and soothing to irritation, with a tendency to check secretion. Taken internally it operates to allay gastric irritability and to control diarrhœa, especially when the diarrhœa is caused by acidity of the intestinal contents. From the conjunction of properties named, lime water is an excellent alkaline wash in skin disease, and is a standard remedy to subdue vomiting and combat the diarrhœa of acidity. In its internal use by far the best way of giving is in mixture with fresh, ice-cold milk. In such mixture, even when "half and half" in strength, the disagreeable lime taste is almost wholly lost, while at the same time the medicinal efficacy of the lime is enhanced, and the patient is nourished by the milk. In obstinate vomiting, indeed, nothing surpasses the administration of small quantities of ice-cold lime water and milk, frequently repeated, to the exclusion of all other medicine and nutriment, both. In ordinary cases, the lime water need not be in greater proportion to the milk than one part to two, three, or four. If the stomach be not too sensitive, such mixtures may be administered quite freely; but yet the *habitual* use of lime water in milk, in milk-fed individuals, such as infants, is objectionable. For occasional use, lime water is so innocent that it is hardly possible to assign any exact dose, but a tablespoonful generally suffices for a single giving, to be taken in at least an equal measure of water or milk. A special application of lime water is based on the fact that the tissue of false membranes immersed in the solution rapidly disintegrates. Hence the practice with some to spray the throat, in croup or diphtheria, with atomized lime water. In such procedure, however, it must be remembered that in the amount of spraying practically possible, the quantity of lime water brought into contact with the membrane is very small, and the duration of the contact short.

Lime water, although decidedly alkaline, is not readily absorbed, and consequently is useless for constitutional alkalizing. For such purpose, alkalies of high diffusion power, such as the basic compounds of potassium or lithium, must be used rather than lime.

Besides lime water, the United States Pharmacopœia offers, as a preparation of lime in solution, *Syrupus Calcis*, Syrup of Lime. This syrup is made by treating a triturated mixture of lime and sugar with boiling water, and bringing the solution after filtration to the standard strength of 6.5 per cent., by weight, of lime. In this procedure the lime and sugar chemically unite, and the product, while retaining the alkalinity and physiological properties of free lime, is yet much more soluble in water, as the percentage strength of the syrup attests. Syrup of lime is therefore, medicinally, a sweetened and at the same time a strong solution of lime, and may be used for the internal applications of lime water, only in much smaller dose—one-eighth, namely, of what would be given of the latter-named preparation.

For local application of the soothing properties of lime solutions, an excellent and ingenious preparation of lime is official in the United States Pharmacopœia under the title *Linimentum Calcis*, Lime Liniment, often called *Carron oil*, from the Carron Iron Works, in Scotland, where the liniment acquired great reputation for the treatment of burns among the workmen. The preparation is simply an admixture, in equal parts, of lime water and linseed oil, whereby a lime soap is formed, which being insoluble makes an emulsion with the considerable excess of the oil prescribed by the formula. The oil, however, readily separates from the aqueous portion, and hence the preparation should be well shaken each time before use. Lime liniment combines the protection of a fixed oil with the alkaline and soothing properties of lime, and makes an excellent dressing for painful affections of the skin, such as burns, both allaying pain and promoting healing. It is applied clear.

Calcium Carbonate: $CaCO_3$.—Calcium carbonate is represented in the United States Pharmacopœia by two preparations. *Creta Præparata*, Prepared Chalk, is the native article freed from most of its impurities by elutriation; and *Calcii Carbonas Præcipitatus*, Precipitated Calcium Carbonate, is the carbonate obtained as precipitated from a solution of calcium chloride by reaction with sodium carbonate. Prepared chalk is in the form of powder, or of little conical pellets, and the precipitated carbonate is always in the condition of a very fine soft powder. Both preparations are permanent in air, odorless and tasteless, and insoluble in water or alcohol, although soluble, with effervescence, in hydrochloric, nitric, or acetic acid.

Calcium carbonate closely resembles slaked lime in its properties, but, being a salt, is less strongly alkaline, and, being wholly insoluble in neutral fluids of aqueous basis, is, locally, absolutely bland. It is medicinally applicable, in a general way, for the same purposes as lime water, and, in addition, because it is a bland, soft, and alkaline absorbent powder, it makes an excellent "dusting powder" to apply as a dressing to skin affections in which the cutaneous surface is moist and tender. Internally the carbonate is available as an antidote to acid poisoning, especially if the acid be sulphuric or oxalic, and is of use to correct idiopathic acidity of the *primæ viæ*, and to allay nausea and check diarrhœa. Being perfectly innocent, either of the forms of the salt may be given freely. For ordinary use in digestive derangements the single dose ranges from 0.65 to 3.00 gm. (gr. x. to xlv.). The medicine may be given as a powder, but administration in mixture is more common. The following pharmaceutical preparations are official in the United States Pharmacopœia: *Pulvis Cretæ Compositus*, Compound Chalk Powder. This consists of three parts of prepared chalk, two of powdered acacia, and five of powdered sugar, mixed. This powder is probably official as the basis for making the next named preparation, but yet is itself a convenient chalk powder for direct prescription. *Mistura Cretæ*, Chalk Mixture. This is compounded of two parts of the foregoing compound chalk powder and four parts each of water and cinnamon water. The sugar and acacia of the compound chalk powder dissolve and the slightly viscid solution resulting is capable, when shaken, of holding the chalk in suspension. The preparation should be freshly made for use, and should be shaken each time before dispensing a dose. It makes a very convenient basis for diarrhœa mixtures, especially in cases of diarrhœa with acidity. It may be given in tablespoonful doses. *Trochisci Cretæ*, Troches of Chalk. Each troche contains 0.25 gm. (about gr. iv.) of prepared chalk with a flavoring of nutmeg.

Normal Calcium (Ortho-) Phosphate: $Ca_3(PO_4)_2$.—This is the phosphate commonly called, for distinction, *bone phosphate*. It is official under the title *Calcii Phosphas Præcipitatus*, Precipitated Calcium Phosphate, and is made by dissolving the phosphate of bone ash by means of hydrochloric acid, and then precipitating it from the solution by the addition of water of ammonia. Such precipitate, washed and dried, presents itself as "a light, white, amorphous powder, odorless and tasteless, and permanent in the air. Almost insoluble in cold water; partly decomposed by boiling water, which dissolves out an acid salt; almost insoluble in acetic acid, except when freshly precipitated; easily soluble in hydrochloric or nitric acid; insoluble in alcohol" (U. S. P.). When freshly precipitated and still moist this phosphate also dissolves wholly in lactic acid.

Calcium phosphate is an important normal ingredient of the animal body, being the calcareous element of the bones and teeth. The use of the salt in medicine has been its internal administration in conditions of disease where there appears to be a deficiency of the substance in the proper tissues, either from assumed lack of supply or from want of power of assimilation. Such conditions are illustrated by rickets, mollities ossium, caries of the teeth, and possibly by scrofula and phthisis. But, as often happens in medication based on purely chemical considerations, the clinical results frequently fall short of the expectation, so much so that many practitioners put but little faith in the present remedy. Very likely the lack of effect of calcium phosphate is principally due to the difficulty of determining the absorption of the salt, partly because of the salt's entire insolubility in other than acid menstrua, and partly because of its low diffusion power. But inasmuch as the phosphate is wholly innocent, locally and constitutionally, it may with propriety be tried in cases in which it seems indicated theoretically. From 0.65 to 2.00 gm. (gr. x. to xxx.) may be given three times a day, larger doses probably being useless through lack of absorption. A convenient form of the medicine is the official preparation of the United States Pharmacopœia, entitled *Syrupus Calcii Lactophosphatis*, Syrup of Calcium Lactophosphate. Precipitated calcium carbonate is dissolved in dilute lactic acid, and to this solution phosphoric acid is added. After certain necessary trituration, the solution of the lactophosphate is filtered, sweetened, and flavored with orange-flower water, and then brought to standard strength by the addition of water. Twenty-five parts, by weight, of calcium carbonate is used to make one thousand measures of the syrup. Should a gelatinous precipitate tend to form upon keeping, a fluidrachm of hydrochloric acid may be added to each pint of the syrup. The preparation may be given in doses of from two to four teaspoonfuls, representing from 0.20 to 0.40 gm. (gr. iij. to vi.) of phosphate.

Calcium Sulphate: $CaSO_4,2H_2O$.—This salt is used in medical art only in the making of plaster-of-Paris dressings. Calicum sulphate occurs native in several conditions, the commonest being the salt combined with two molecules of water constituting the substance *gypsum*. The valuable property of gypsum is that when dehydrated and treated with water it recombines with the latter, and in such combining sets in a hard, dry mass. Gypsum is dehydrated by heat, which should not exceed 120° C.; for if carried too high (above 204° C.) the gypsum — called then technically *dead-burnt* — recombines with water but slowly and the product does not solidify. As properly dehydrated and pulverized the product is a white powder, without odor or taste, called *burnt gypsum* or *plaster-of-Paris*. Plaster-of-Paris is official in the United States Pharmacopœia under the title *Calcii Sulphas Exsiccatus*, Dried Calcium Sulphate. Mixed with two parts of water, plaster-of-Paris makes a soft, creamy paste, which in the course of from fifteen to twenty minutes gradually stiffens, until at last it sets into a perfectly hard and dry mass. During the setting a moderate degree of heat is evolved (not beyond the range perfectly bearable by the human skin), and the mass very slightly expands. Applied, therefore, as a casing to a limb, the dressing may be perfectly fitted without fear of shrinkage upon setting. After setting, the plaster-of-Paris neither softens nor dissolves by treatment with water, the solubility of calcium sulphate in water being only about one part in five hundred. For use in surgery the plaster-of-Paris paste may be applied by smearing it upon the bandaged limb so as to form a casing, but a far better way is to impregnate a flannel bandage thoroughly with the dry plaster, roll it loosely, and when the dressing is to be fitted dip the roller into a vessel of water until bubbles cease to be evolved and then apply in the usual manner, but without reverses. Before so applying, however, the skin should be protected by a plain bandage, or, where appropriate, by a thread glove or a stocking.

Plaster-of-Paris should be kept in well-closed vessels, else, attracting moisture from the atmosphere, it will become partially hydrated. *Edward Curtis.*

CALCULI. See *Concretions.*

CALCULI, CUTANEOUS. See *Milium.*

CALEDONIA SPRINGS.—Post-Office.—Caledonia Springs, Ontario, Canada. Hotel, the Grand Hotel.

Access.—From Montreal and Ottawa by Canadian Pacific Railway, or by the Ottawa Navigation Company steamers.

Analysis, by Sterry Hunt. In one thousand parts:

Solids.	Gas Spring.	Saline Spring.	White Sulphur Spring.	Duncan or Intermittent Spring.
Chloride of sodium	6.9675	6.4409	3.5430	12.2500
Chloride of potassium	.0309	.0296	.0230	.0305
Chloride of calcium	...	..	......	.2870
Chloride of magnesium	...	...	......	1.0338
Bromide of sodium	.2150	.0169	.0100	
Bromide of magnesium	.	.	.. ...	.0238
Iodide of sodium	.0005	.0014		
Iodide of magnesium	...	.	.	.0021
Sulphate of soda	.0053	.0048	.0183	
Carbonate of soda	.0485	.1762	.4558	
Carbonate of lime	.1480	.1175	.2100	.1264
Carbonate of magnesium	.5262	.5172	.2940	.8672
Carbonate of iron	Trace.	Trace.	Trace.	Trace.
Alumina	.0044	...	.0026	
Silica	.0310	.0425	.0840	.0225
	7.9773	7.3470	4.6407	14.6433

These springs are carbonated saline, mildly charged with carbonic acid gas. There escapes with the water of the Gas Spring a large amount of carbureted hydrogen gas. The water of the White Sulphur Spring contains sulphureted hydrogen equal to about one cubic inch per gallon. The springs are situated on a level plateau which extends for many miles in all directions, the country being open and well cultivated. The Grand Hotel is commodious and comfortable. The management is excellent. All modern methods for utilizing the waters are at hand, and a physician resides at the hotel during the season. There are also a number of boarding-houses and cottages on the grounds, all of which are under the control of the company. The hotels are open from June to October.

The Caledonia Springs are the best known of Canadian mineral springs, and are resorted to by large numbers from Canada and the United States, particularly from the South. In addition to the water consumed at the springs large quantities are bottled and sent to all parts of Canada and the United States. *Beaumont Small.*

CALENDULA. MARIGOLD.—"The florets of *Calendula officinalis* L. (fam. *Compositæ*)" (U. S. P.). These florets are strap-shaped, nearly half an inch long, three-toothed, hairy upon the tube, of a bright yellow color, pistillate, with a two-branched style. The odor is characteristic, the taste aromatic and bitterish. They contain a little volatile oil and an amaroid, with resin and an abundance of the bright yellow coloring matter, *Calendulin*, which is inactive. The drug possesses very slight aromatic-bitter properties, but is chiefly used for coloring purposes. It is now much less used than formerly, and will doubtless be omitted from the next edition of the Pharmacopœia. The dose is 1 to 2 gm. (gr. xv. to xxx.).

The herb possesses similar properties, but is even weaker and contains much more mucilage. It has been used similarly, as well as for making poultices. Through an error, this, instead of the florets, was incorporated in the preceding edition of the Pharmacopœia. *Henry H. Rusby.*

CALIFORNIA, SOUTHERN.—In this article only a brief and general account of the climate of Southern California will be given, as the principal resorts and sections will receive especial mention under their respective heads, in regular alphabetical order.

Southern California is an irregular area of territory, equal in extent to England and Wales, lying between latitude 35° 40′ and 32° 30′, with a coast line of 330 miles. It is bounded on the north by the Tehachapi Mountains, which are spurs of the coast ranges and Sierra Nevada; on the east by the Colorado River; on the south by the Mexican frontier; and on the west and southwest by the Pacific Ocean. In the western portion is the southern coast range, forming the eastern boundary of the *coast plain*, which contains numerous beautiful valleys, such as the Santa Clara and Santa Buena Ventura. This coast plain extends for 150 miles, and is from 15 to 25 miles in depth. Between the coast range and the Sierra Madre and San Bernardino ranges lies the *interior plain*, 200 miles in length and from 15 to 30 miles in depth. Here is the great San Gabriel Valley, which has been called the Lombardy of America, and numerous lesser valleys. "Between the coast plain and the long interior valley, the coast range of mountains is broken, and, opposite the Los Angeles plains, entirely disappears for a space. The whole country becomes thus a great open coast-land facing the south, and with the high Sierra for a background."* North and east of the Sierra, or inland range, lie the Mojave and Colorado deserts. It is with the resorts on or near the coast, or with those in the interior plain, that we have especially to deal as climatic stations, such as Santa Barbara, San Diego, Coronado Beach, on the coast; or, farther inland, Riverside, Redlands, San Bernardino, and others. The soil is composed largely of disintegrated granite, which is sandy and porous, and in many localities there are also large patches of adobe or red clay.

FIG. 1072.—Bay of San Diego, Southern California.

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* "California of the South," by Walter Lindley and J. P. Widney, 1888.

Climatic Data.	San Diego, Latitude, 32° 43′; Longitude, 117° 10′.						Santa Barbara, Latitude, 34° 28′; Longitude, 119° 41′.						Los Angeles, Latitude, 34° 3′; Longitude, 118° 5′.					
	Jan.	April.	July.	Nov.	Winter	Year.	Jan.	April.	July.	Nov.	Winter	Year.	Jan.	April.	July.	Nov.	Winter	Year.
Temperature—																		
Average or normal	53.6°	57.7°	67.1°	58.2°	54.5°	60.4°	51.2°	60.5°	66.8°	56.0°	54.01°	60.7°	54.1°	58.0°	71.1°	62.0°	53.5°	62.0°
Average daily range ..	17.3	14.1	11.6	18.1	16	14.3	18	18	19	25	....	19.1	20.1	20.2	23.1	24.5		
Mean of warmest	61.8	65.3	73.5	66.8	..	...	57.8	65	69.2	62.3	....	....	62.9	69.2	82	70.7		
Mean of coldest	44.5	51.2	61.9	48.7	...	.	42.8	52	69.7	53	...	...	42.8	49	58.9	46.2		
Highest or maximum ..	78	87	86	85	.	..	83	86	89	82	...	...	82	94	98.1	86		
Lowest or minimum....	32	39	54	33		..	38	41	44	40	....	...	30	39	51.2	34.2		
Humidity—																		
Mean relative..........	71.2	72.4	76.4%	66.4	70.9%	72.9%	71%	67%	72%	64%	...	73%	62.9%	70.1%	69.4%	57.3%	63.6%	66.6%
Precipitation—																		
Average in inches ...	1.85	0.68	0.02	0.70	6.04	9.49	3.7	1.4	....	1.6	11.77	17.6	3.9	1.3	....	.95	8.65	18
Wind—																		
Prevailing direction ...	N. E.	W.	W.	N.W.	N.E.	W.	....	....	...	....	....	W.	N.E.	W.	W.	N.E.	N.E.	W.
Average hourly velocity in miles	5.1	6.6	6.3	5.1	5.4	5.9	4.3	5.3	5.1	3	.	4.6	5.5	5.4	4.9	4.9	5.4	5.1
Weather—																		
Average number of clear days.	11.3	10.2	8.2	13.5	33.5	122.7	24	16	27	13	....	231	17.5	10.2	10.4	18.8	....	171.3
Average number of fair days.	11.2	11.9	16.1	10	33.7	155.1	1	6	3	9	...	63	8.5	12.5	19.7	9.3	26.6	144.8
Average number of clear and fair days...	22.5	22.1	24.3	23.5	67.2	277.8	25	22	30	22	..	294	26	22.7	30.1	28.1	74.5	316.1

The main features of the climate of Southern California are warmth, equability, a large amount of sunshine and a small amount of annual rainfall. "Taken as a whole," says Professor Hilgard, "Southern California corresponds in its climatic features and adaptation to the Mediterranean region of Europe and Africa; a grand Riviera with a partial background of the desert as well, where the date palm and ostrich find a congenial home, and alluvial plains equalling in riches the famed delta of the Nile."

"Warm winters, comfortably cool summers, very low rainfall, and rainfall so distributed as to divide the year into a dry and a so-called rainy season, almost unparalleled preponderance of cloudless weather, and (in consequence of the low latitude) a long duration of the daily sunshine in winter—all these are characteristic of every portion of Southern California. In comparative humidity of the atmosphere lies the chief difference between its coast stations and those lying at a greater or less distance from its coast line" (Huntington Richards).

"The warmth and equability of this climate depends," says Dr. C. F. Williams,[*] "upon three factors: its southern latitude, its protection by the various mountain ranges from cold, northerly or easterly winds, and the influence of the Pacific, and especially the warm Kuro Siwo, or Black Japan current, which washes the shores of the Western States."

There exists a certain misapprehension regarding the matter of dryness of this climate. For example, as good an authority as Lindsay refers to it as "intensely dry." Williams calls it a "dry, warm climate," and Remodino remarks that "every term in the meteorological vocabulary relative to moisture and dryness has been conscientiously applied to the region." The fact is, that the coast districts, like all other coast resorts, exhibit the features of a marine climate, one of which is a large amount of moisture, and upon this fact, as we know, depend the coolness and equability characteristic of such a climate.

If one would find real dryness he must, as Solly says, seek it beyond the mountains in the desert country. If, however, "he seeks more days of sunshine and opportunities for outdoor life, with a more equable temperature and an average humidity a little greater than that of New York or Boston, he can find what he desires at Santa Barbara or San Diego." Even as far inland as Riverside, more than 50 miles from the coast, the humidity is appreciably greater than at Aiken, for example, and very considerably greater than at most of the Colorado, New Mexico, and Arizona resorts. Still further, one must bear in mind the fact, as Solly says, "that, in spite of the great amount of sunshine during the day in California, the foggy and damp nights and mornings take up a great part of the twenty-four hours." This authority notes the following observation made by himself at Redlands: "On one occasion when at 4:30 P.M. the relative humidity, as indicated by the hygrometer, was fifty-five per cent., at 6 P.M. it had increased to eighty per cent." "The difference between noonday and midnight temperature," says Kate Sanborn,[*] "between sun and shade, is something to be learned and guarded against."

RIVERSIDE, 60 MILES FROM THE COAST, 850 FEET ABOVE SEA LEVEL.

	Jan.	April.	July.	Nov.	Year.
Mean monthly temp..	53.1°	61.2°	77.0°	62.2°	62.0°
Maximum temp..... .	78.2	89.2	101.2	89.2	
Minimum temp..... .	32.7	39.2	60.5	39.5	
Relative humidity....	67%[1]	56%[2]	63%[3]	76%[4]	67%
Precipitation					
Average in inches	3.27	1.43	...	1.35	10
Wind					
Prevailing direction	..	...	S. W.	....	W.
Weather					
Average number of clear days........	16	20	29	15	(1890) 208
Average number of fair days	...	.	...	....	105
Average number of cloudy days......	14	9	1	10	52

From July, 1885, to July, 1886, there were 280 absolutely clear days, and 38 days of rain or showers.

[1] For the spring of 1888. [2] Summer of 1888. [3] Autumn of 1888. [4] Winter of 1888.

The accompanying tables of climatic data of San Diego, Santa Barbara, Los Angeles, and Riverside exhibit, so far as such statistics can, some of the principal climatic features of this region. As there is no government weather station either at Santa Barbara or at Riverside, the figures for these places must be considered as only approximately correct. A general similarity will be noted in the climates of all these places. As one goes inland the relative humidity is seen to lessen. The number of fair and clear days is very large, the precipitation very small, the prevailing winds are from the west, and there is no great wind velocity. At Riverside, a distance of 50 miles or more from the coast, the maximum temperature, especially in summer, is seen to increase. A peculiarity of this climate, not indicated in climatic charts, is the great difference between the character of the atmosphere during the day and during the night. At night the humidity is greatly increased, an example of which has already been noted in the case of Redlands. This increase of moisture by night renders the air chilly and raw, and in many cases would prevent the free admission of night air into the sleeping-rooms. Even during the day this chilliness is experienced in passing from the sunshine into the shade, and when the wind blows.

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[*] "Aero-Therapeutics," 1894.

[*] "A Truthful Woman in Southern California," 1895.

Another peculiarity is the frequent night fog, present not only on the coast, but extending many miles up the valleys. These fogs, which are most prevalent during the spring and summer, appear about nightfall and disappear during the early forenoon. Occasionally they persist during a part or the whole of the day. The annual mean average number of foggy nights at Los Angeles, for thirteen years, was 57. In 1891 there were 22 fogs in San Diego, 12 in 1893, and 26 in 1894. At Santa Barbara there were 73 fogs in 1894.

The rainfall, which is small in any event, except on the highest summits, occurs in the winter, which is the rainy season. This rainy season, however, varies very greatly from year to year. Sometimes the rain is delayed for weeks, and then it may rain continuously for days. One cannot predict from the annual average precipitation what the rainfall will be for any single year. For instance, Los Angeles has a normal precipitation of 18 inches, but in 1881 it was 5.6 inches, and in 1884, 40.5 inches. The normal of San Diego is 10 inches, but it has had a minimum of 3.71 inches and a maximum of 25.97 inches. The heaviest rainfall occurs in the months of December, January, and February. Even January, however, may be a very dry month. In the desert regions there is almost no rain. Thus, for instance, at Indio the annual average for nine years was 2.32 inches. It is to be remembered, as Solly points out, that even in the rainy season the monthly rainfall is not usually more than the normal monthly rainfall for Eastern cities, and there are longer periods of fine weather. "The welcome rains," he continues, "bring a vivid green to the brown valleys and hills, and the beautiful 'procession of flowers,' which continues from December to May, enraptures Eastern visitors."

Regarding the winds there is one point which the tables do not show, and which, as Widney says, most impresses the observer in his study of this meteorological factor, and that is, their regularity. One can be assured that at certain seasons of the year the wind will blow from a certain quarter, and rise at a certain time each day. Further, he knows that if the wind blows from a certain quarter, certain climatic conditions will follow: if it blows from one direction a moist atmosphere and rain will result; if from another, a dry atmosphere, cold in winter, hot in summer; if from still another, there results clear, cool weather with moderate moisture.

Much has been written about the great variety of climate to be found in Southern California. For instance, Dr. Edwards writes* thus: "Within a few hours from any given point one may obtain the climate to his liking." Such sweeping statements are manifestly misleading, for where in any inhabitable locality in Southern California can be found the cool, dry air furnished in the elevated plains of Arizona, New Mexico, or Colorado, at such resorts as Tucson, Santa Fé, and Colorado Springs?

In addition to the favorable climatic conditions of this marvellous section of country, there is the fascinating charm of beautiful and diversified scenery—sea coast and mountain—with varied and luxuriant vegetation.

A great variety of fruits of both tropical and temperate regions are produced here: oranges, lemons, grapes, figs, olives, guavas, pineapples, pears, peaches, and strawberries all the year round. Riverside has its famous Magnolia Avenue and orange groves; Sierra Madre its vineyards; Santa Monica its ostrich farm; and San Diego its beautiful Coronado Beach, which Charles Dudley Warner calls, in "Our Italy," "An unique corner of the earth." The temperature of the sea water is 60° F. or more throughout the year, so that one can enjoy sea bathing at any time of year. There are also abundant opportunities for hunting, fishing, camping, riding, and almost every kind of outdoor diversion. If we consider all this, and the fact of an almost continuous sunshine, we can understand how outdoor life becomes a delight hardly imaginable until realized.

Here, also, one cannot only take the open-air treatment, but, while doing so, can, if strength permits, occupy himself in making a new home, and in light and pleasing work in garden and vineyard. As Dr. Richards says: "Southern California is not only a good winter residence, but a health-giving and health-restoring home for residence all the year round."

Formerly—and to a large extent at the present time—Southern California was considered one of the most favorable resorts in this country for pulmonary tuberculosis, and probably more invalids suffering from this disease frequented this region than any other class. Moreover, no discrimination appears to have been made regarding the stage or condition of the pulmonary trouble suitable for this climate. In the writer's opinion, this will not be so much the case in the future, since experience is proving more and more conclusively every day that the sanatorium treatment of consumption is affording the best results, and that the situation of the sanatorium, climatically considered, does not make so much difference, provided pure air, a dry soil, freedom from high winds, and a reasonable amount of sunshine are assured. Almost every State can offer these simple climatic conditions, and hence can have its own sanatorium.

This plan, moreover, possesses the further advantage, so much emphasized by the German phthisio-therapeutists, that the consumptive is treated under a climate like that in which, if cured, he will continue to live.

There are no published statistics known to the writer of the results of treatment of consumption by the Southern California climate, so that no comparison is possible with the results of other resorts and of sanatorium treatment. That this climate offers excellent opportunities for the open-air treatment of phthisis no one will deny, but that there is any striking advantage in it over that of many other resorts there are no statistics at hand to prove.

In the writer's opinion, Southern California, in the future, will be visited not so exclusively by consumptives as heretofore, but by the large class of invalids requiring a mild, equable, sunny climate, with ample opportunity for outdoor life and diversion; such as the feeble from age or inherited weakness, convalescents from various acute diseases, those suffering from malaria, catarrhal affections, chronic bronchitis, renal and cardiac diseases, scrofulous children, and those individuals who are in the quiescent state of pulmonary tuberculosis without pyrexia. Finally, to this list must be added that increasingly large number of persons who desire to escape the inclemency of a Northern winter.

The conditions for which this climate is unfavorable or doubtful are phthisis with acute symptoms, certain diseases of the nervous system, laryngeal phthisis, eczema, asthma, and rheumatism.

There has been much exaggerated and immoderate writing on the climate of Southern California, not infrequently from selfish and commercial reasons, as also from superficial and inadequate knowledge. One physician writes of San Diego that it presents "all the factors requisite in a perfect climate." Another, writing of Pasadena, says that it is "the greatest all-the-year-round-health resort in the world," and so on.

Such wild statements, generally made without any accompanying meteorological data, seem quite unnecessary in regard to a climate which in fact and truth possesses so many points of excellence as does that of Southern California. *Edward O. Otis.*

CALIFORNIA GEYSERS, THE. — Sonoma County, California. Hotel and cottages. This marvellous region is located in the northeastern part of Sonoma County, about 100 miles north of San Francisco, 16 miles from Cloverdale, and 26 miles from Calistoga. Formerly tourists rode on horseback for many miles to visit this realm of fumaroles and solfataras, which is situated about 1,700 feet above the sea level; but, thanks to the push and

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* "Two Health Seekers in Southern California," 1897.

Analysis of Waters from Several Springs at the California Geysers.

Contents per United States Gallon, Expressed in Grains.	Lemonade Spring. Temp. 103° F.	Witches' Caldron. Temp. 212° F.	Acid Spring. Temp. 140° F.	Alum Spring. Temp. 130° F.	Iron Geyser Creek, below Alum Spring. Temp. 96° F.	Spring on side of hill near river. Temp. 138° F.	Iron Spring north of hotel. Temp. 70° F.	Indian Spring (second). Temp. 101° F.	Mud Indian Spring. Temp. 100° F.	Spring little above Indian Spring. Temp. 105° F.	Hot sulphur water above bathhouse. Temp. 140° F.	Devil's Tea-Kettle. Temp. 212° F.
Potassium bisulphate	7.53	0.42	1.14			.						
Potassium sulphate	....	....	....	....	....	....	....	0.21				
Sodium bisulphate	53.91	39.82	9.62	5.14	....	....	....	....	17.12	....	....	98.16
Sodium sulphate	...	...	...	....	3.15	3.23	....	3.29	....	....	2.36	
Sodium carbonate	...	...	....	....	....	....	....	1.40				
Calcium sulphate	...	6.98	4.44	3.81	5.34	1.10	3.32	....	6.42	8.72	.65	4.36
Calcium carbonate	..	....	....	....	....	....	....	7.35				
Calcium silicate	...	....	. .	....	....	10.18						
Calcium borate	..	....	....	..	....	....	....	....	....	....	6.62	
Magnesium sulphate	40.73	9.62	91.29	34.49	16.66	....	2.52	....	59.33	41.12	....	39.09
Magnesium carbonate	...	....	....	....	....	....	....	15.47				
Magnesium silicate	.	...	...	...	....	15.46						
Magnesium borate	....	...	...	....	....	....	....	....	....	....	17.31	
Iron sulphate	12.25	..	16.63	7.34	.08	.11	....	....	....	28.81	.16	
Iron carbonate	...	...	...	....	....	....	.12	.07				
Aluminum sulphate	32.02	2.04	20.62	63.82	....	.20	....	....	22.78	118.78	2.39	31.16
Alumina	...	.27	...	....	.89	....	.17	.18				
Free sulphuric acid	31.82	...	154.37	6.45	....	....	....	....	32.30	5.75	....	110.64
Hydrochloric acid	1.19											
Silicic acid	16.50	4.37	21.11	17.26	3.50	17.25	.99	5.42	12.25	18.08	8.63	12.83
Sulphureted hydrogen	Sat.	Sat.	Sat.	Sat.	Sat.	....	....	Sat.	Sat.	Sat.	Sat.	Sat.
Boric acid	...	..	Str.	Traces.	..	....	....	....	....	....	Str.	Traces.
Total	195 95	63.52	319.22	138.31	29.62	47.53	7.12	33.39	150.20	221.26	38.12	296.24

enterprise of our Western civilization, it may now be reached in a comfortable six horse stage from the termini of the Cloverdale and Calistoga railroads over excellent mountain roads. It is a good plan to go by way of Cloverdale and come back by way of Calistoga, as all the grandeur and beauty of the surrounding country may thus be seen. The following entertaining account of a visit to the geysers is taken from Dr. Anderson's work:

"Leaving Cloverdale after luncheon, comfortably seated in our stage, with an experienced and accommodatingly communicative driver, who takes pleasure in pointing out the many objects of interest, we soon cross the Russian River and commence the ascent. The hills and mountains are robed in evergreen verdure of indigenous flora, gigantic oaks, and towering pines. Here and there the huge boulders and rocky cliffs stand out in bold relief, and as we wind up and around the mountain sides, with the Pluton River many hundred feet below, basking and smiling in the afternoon sun, and rippling along its moss-covered banks and bright-pebbled bottom, with here and there a miniature cascade and waterfall, we feel that words cannot describe the grandeur of the scenery. . . .

"As we gain in altitude the view becomes more and more extended, until our eyes leap with vivid interest from peak to peak and valley to valley for miles around, feasting upon the beauties of nature. Some two or three miles down the cañon, before we reach the geysers, our attention is called to the large white or yellowish-white banks across the cañon. They are known as sulphur banks, and consist of deposits of sulphur and cinnabar, with incrustations of salts of sodium, potassium, magnesium, sulphur, etc. . . . Near these sulphur banks are found the famous Indian Springs, at which Edwin Forrest camped for one season and was completely restored to health."

The waters are diuretic, laxative, and antacid, and are valuable in dyspepsia, torpidity of the liver and bowels, and in renal and cystic diseases. (See table for analysis.)

Near by are the real "Indian Mud Springs," which are highly extolled in the treatment of chronic rheumatism, gout, arthritis, and synovitis, and scrofulous and cutaneous contaminations. (See table.)

". . . After a few more horseshoe curves have been passed and several more magnificent landscapes have been mentally photographed on the brain, we reach the geyser resort. The many cosey cottages, the hotels and grounds, are situated in a leafy dell on the side of the mountain opposite the Geyser Cañon. The huge oaks and pines afford pleasant shade to the commodious verandas as we sit and enjoy the pure, dry, invigorating, and exhilarating mountain air and picturesque scenery which surround us on every side."

The geysers are wonderful and picturesque exhibitions of the nearly extinct volcanic forces slumbering beneath the romantic "Devil's Cañon." The region covers an area of about four hundred acres, most of the activity, however, being confined to the "Devil's" or "Geyser" cañon, comprising about sixty acres. Collectively, the springs, hot and cold, flow about one hundred thousand gallons daily.

From the foregoing analyses (see above) made by Prof. Thomas Price it will be observed that at the geysers can be found probably as great a variety of mineral waters as at any other place on the continent, or perhaps in the world. When the improvements now contemplated are carried out, the "geysers" will be one of the world's greatest sanatoriums.

There are other geysers in various parts of California, but they have not so far reached any great importance as health resorts. Near Litton's Station, in Sonoma County, some few miles from Geyserville, is a pleasant resort known as the "Geyser Spa" or "Soda Springs." The surrounding country is picturesque, and the climate mild and salubrious. A large number of people go to Geyser Spa every year. The waters are highly esteemed for their antacid, diuretic, and aperient properties. The following analysis was made by Dr. Winslow Anderson in 1888:

One United States Gallon Contains:

Solids.	Grains.
Sodium chloride	8.93
Sodium carbonate	4.97
Sodium bicarbonate	21.16
Sodium sulphate	2.60
Potassium carbonate	Trace.
Magnesium bicarbonate	9.03
Magnesium sulphate	1.14
Calcium carbonate	4.90
Ferrous carbonate	2.09
Silica	3.75
Organic matter	Trace.
Total solids	58.57

Carbonic acid gas, saturated.

A previous analysis made by Bauer and Price yielded results almost identical with Anderson's.

James K. Crook.

CALIFORNIA POPPY. See *Eschscholtzia.*

CALIFORNIA SELTZER SPRINGS. — Mendocino County, California. These springs are pleasantly located in the Coast Range, 12 miles from Cloverdale. The surroundings are picturesque, and the climate salubrious. There are comfortable accommodations for visitors.

On analysis the Seltzer Spring was found by Anderson to be composed as follows:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	17.15
Sodium bicarbonate	53.00
Sodium carbonate	Trace.
Magnesium carbonate	44.60
Ferrous carbonate	Trace.
Calcium carbonate	72.40
Organic matter	Trace.
Silica	Trace.
Total solids	187.15
Free carbonic acid gas	1800 cu. in.
Temperature of water	57° F.

The waters are sparkling and quite palatable. They have a diuretic and aperient action, and are beneficial in dyspepsia with acid eructations, constipation, acid states of the urine, cystitis, etc. They belong to the alkaline-carbonated class. *James K. Crook.*

CALISAYA. See *Cinchona.*

CALISTOGA SPRINGS.—Napa County, California. These valuable springs are situated 9 miles south of Mount St. Helena. There are two sets of springs, one in the city of Calistoga and the other just outside the town. They are very similar in chemical composition. There were at one time an excellent hotel and many fine cottages at the springs, but since the fire in 1868, which destroyed the former and several of the latter, the resort has changed hands many times, and has been allowed to run down. It is said that the present proprietor contemplates fully restoring the once handsome resort.

The mineral springs number some twenty or more, and range in temperature from 75° to 186° F. They are used for drinking and bathing purposes, and have acquired considerable reputation. The following analysis of the water of one of the springs at Magnolia Hotel was made by Dr. Anderson:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	20.76
Sodium carbonate	5.10
Sodium sulphate	1.75
Sodium iodide	.16
Potassium iodide	Trace.
Magnesium sulphate	2.90
Calcium chloride	5.57
Calcium sulphate	.63
Alumina	.47
Silica	4.55
Organic matter	Trace.
Total solids	41.89
Free sulphureted hydrogen gas	4.75 cu. in.
Temperature of water	95° F.

The following analysis shows the mineral ingredients of the Hot Swimming Pool on the grounds of the late Senator Stanford:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium chloride	23.07
Sodium carbonate	2.19
Sodium sulphate	6.92
Sodium iodide	.73
Potassium iodide	.21
Potassium carbonate	.76
Magnesium sulphate	1.16
Magnesium chloride	.40
Calcium chloride	.96
Calcium sulphate	1.25
Ferrous protoxide	.45
Manganese	Trace.
Alumina	.27
Silica	3.61
Organic matter	Traces.
Total solids	41.98
Sulphureted hydrogen gas	6.30 cu. in.
Temperature of water	121.6° F.

The springs have gained considerable celebrity in obstinate cases of syphilitic contamination, rheumatism, etc. *James K. Crook.*

CALLOSITAS.—(*Callus, Hardened Skin*).—SYNONYMS.—Callosity; Tyloma; Tylosis; Callus; Keratoma; (*Fr.*) Durillon.

DEFINITION.—A circumscribed thickening and welding of the horny layer produced by intermittent friction or pressure.

Callosities are congenital or acquired. The congenital callosities, however, are now usually discussed separately under the heading of Keratodermia or Tylosis Palmæ et Plantæ. The latter are diffuse or circumscribed keratomata, usually symmetrically distributed over the palms or soles, or over both, springing from an apparently normal skin or surrounded by a red areola. Arsenic from prolonged use often causes a similar condition.

Peculiar symmetrical horny hypertrophies are sometimes associated with certain neuroses or unknown constitutional conditions; these are often preceded by mild inflammatory symptoms. The so-called syphilitic keratodermias should probably be placed with the latter class. The term callosity is more properly applied to the acquired form, which is essentially a result of external irritation by friction, by *intermittent* pressure, or rarely by chemicals. *Continuous* pressure or friction causes active inflammatory reaction, either vesiculation, or pustulation, or sloughing. The result of this milder trauma is best seen upon the hands of mechanics, oarsmen, wood-choppers, and those whose occupations necessitate this irritation, as yellowish or yellowish-brown, circumscribed, round, or irregularly shaped flat or raised patches of thickened skin that are hard and resistant to the touch. They occur usually over the bony prominences or bursæ, and spring from apparently normal skin.

Callosities may occur upon any portion of the body subjected to the exciting factor. The feet, next to the hands, are most frequently affected, due to walking barefoot or to badly fitting shoes.

This thickening of the horny cells is an effort of nature to protect the more delicate underlying structures. Histologically there is probably no actual increase in the production of epithelial cells but a "welding" (Unna) together of the pre-existing horny cells by the friction, into a homogeneous horny mass; thus the cells normally thrown off are retained, producing an apparent increase and an actual thickening. Except in those cases in which the condition results from a more violent trauma, no marked inflammatory symptoms, aside from a slight dilatation of the vessels, are seen.

The acquired callosities can be differentiated from the keratodermias by the history and symmetry of the latter, though it must be remembered that in those who are particularly susceptible, very little friction may produce a marked callus.

The syphilitic conditions of the palms and soles usually begin in the centre and not over the bony prominences, spread peripherally, and at some points the horny layer is often split up or undermined.

The treatment of callosities is first to remove the cause, whatever that may be. To soften and remove the thickened horny layer salicylic acid is the remedy *par excellence.* It can be used in form of a plaster (10 to 20 per cent.) or in flexible collodion (ʒ ss.– ℥ i.). Either should be applied for several days, when the affected part is immersed in very hot water for several minutes and the dead, macerated cells removed by gently scraping with a curette or dull knife blade. This procedure is repeated as often as necessary until the skin is reduced to its normal thickness, when a mild tar application will effectually complete the cure. *William A. Hardaway.*

CALORIMETRY (L. *calor,* heat + Gr. *μέτρον,* measure) is the name applied to the process of measuring the heat given off from any body or substance; and a calorimeter is an instrument for making such measurement.

Animal calorimetry is determining the heat produced and the heat given off by an animal. This is accomplished either by indirect or by direct calorimetry, each of which will be described in its proper place. A respiration calorimeter is one which is so arranged as to allow the inspired and the expired air to be analyzed at the same time that direct calorimetric observations are made.

The unit of measure for heat in calorimetry is the *calorie.** This is the amount of heat required to raise 1 gm. of distilled water 1° C.†

In work involving small amounts of heat this is commonly used, and is often spoken of as a small calorie.‡ Another unit, often called simply "calorie," is the amount of heat required to raise 1 kgm. of water 1° C. This is called a large calorie (or sometimes a great calorie) to distinguish it from the small calorie. It is used when larger amounts of heat are to be measured. One large calorie = 1,000 small calories. When the term "calorie" is used in connection with physiological experiments, the large calorie is generally meant. It will be so used in the present article. Other heat units in terms of different thermometer scales and different quantities of water were formerly employed in calorimetry, but their use is now being fast given up in favor of the caloric or large calorie —a change which is highly desirable for the sake of uniformity. In engineering the B. T. U. (British thermal unit) is still widely employed even in papers of unquestioned scientific standing. Its use in physiology was, for the most part, abandoned a decade or more ago.

In physics and in chemistry calorimeters are mostly used for determining the specific heats of different substances, for determining the heat of various combustions, and for determining the latent heat of fusion and of vaporization. It is not within the scope of the present article to discuss these methods or the instruments involved.

In the sciences more closely allied to medicine, calorimetry is used to study the phenomena of animal heat and its regulation in the healthy body—physiology; to study the same in fever—pathology; and to study the effect of drugs and poisons which influence body temperature—experimental pharmacology. The classic researches with the calorimeter in these fields will be discussed in the respective sections of this article, which for convenience of reference will be divided as follows:

§ 1. Introductory and historical.
§ 2. Indirect calorimetry.
§ 3. Direct calorimetry.
§ 4. Description of calorimeters employed in classical medical researches.
§ 5. Calorimetry in physiology.
§ 6. Calorimetry in pathology.
§ 7. Calorimetry in experimental pharmacology.

§ 1. INTRODUCTORY AND HISTORICAL.—Our modern conception of animal heat, viz., that it is produced by the slow oxidation of combustible materials in the body, first became possible with the establishment of our present theory of combustion, which dates back to the last quarter of the eighteenth century, and is dependent chiefly upon the brilliant researches and conclusions of Lavoisier (1772–94). Prior to that epoch, there was a perfect chaos of speculative theories regarding animal heat. Haller taught that this heat was produced by the friction of the blood in the heart and in the vessels; that every heart beat put the tissues on a stretch, that between the heart beats they rebounded by their own elasticity, and all these motions produced heat by friction. Summing up he says: "De cordis primo insito calore nulla dubitatio superest." Van Helmont attributed animal heat to a vital spirit. Descartes ascribed it to a fermentation of the blood in the cavities of the heart. Hamberger held that the heat of the body was comparable to the heat of a dunghill. All these theories had their followers at the time the combustion theory entered the field—the theory of Haller being, probably, the dominant one.

Animal heat soon came in for its share of investigation in connection with the general question of the origin of heat which was occupying the attention of investigators in England and in France at the epoch referred to.

The first calorimetric researches on animals were made by Crawford in Edinburgh, and an account of them was published (1779) in a pamphlet entitled "Experiments and Observations on Animal Heat and the Inflammation of Combustible Bodies, Being an Attempt to Resolve These Phenomena into a General Law of Nature." In this work Crawford clearly secures for himself and for England the priority in calorimetric observations on animal heat, and the title of his pamphlet, as well as the matter it contains, leaves no doubt as to his position in ascribing animal heat to an oxidation of combustible substances in the body.

Crawford's work has not received the recognition it deserves, and, even in English books, one occasionally sees the statement that Lavoisier was the first to use the calorimeter in experiments on animal heat. Lavoisier* had already, in 1777, from his analyses of expired air, published the fact that in the lungs the air lost oxygen and took up carbon dioxide; but his calorimetric observations were first published† in conjunction with Laplace in the year following the appearance of Crawford's pamphlet.

Unfortunately, Crawford used the nomenclature of the old phlogiston theory to which English scientists still clung, but he measured the heat given off by guinea-pigs, and he also analyzed the air they breathed during the experiment, and his conclusions, translated into the language of modern chemistry, may fairly be given as follows: Both CO_2 and H_2O are given off by the animal from its lungs. The blood brings back from the capillaries a combustible material for which the oxygen has a great affinity. The oxygen unites with this and produces heat which the blood distributes through the body. The heat is produced in the process by which the O is transformed into CO_2 or H_2O. "Animal heat seems to depend upon a process similar to a chemical elective attraction." Considering that the whole theory of chemical affinity was then in its infancy, one can hardly expect a more definite statement than this from a pioneer series of experiments.

It will be seen that Crawford places the seat of combustion in the blood in the lungs. In this he takes a view expressed by Lavoisier, two years before, although Lavoisier, contrary to the way he is generally quoted, clearly states the possibility that there may be only a gaseous exchange in the lungs, the true oxidation taking place farther back—a position now universally held to be the correct one.

§ 2. INDIRECT CALORIMETRY.—"Indirect calorimetry" is the name given to the method by which the heat produced and the heat given off from the body are not measured directly, but are calculated from the amount of oxygen used, and the amount of oxidized waste products given off from the body during a given period taken in connection with the body temperature. This method yields accurate results when the experiments are continued uninterruptedly for a considerable time—say twenty-four hours—and when cognizance is taken of the composition of the ingesta and of *all* the waste products thrown off by the lungs, skin, kidneys, and intestines, and the temperature of the body is also carefully recorded. In many experiments the observers have considered only part of the waste products, and the experiments have been of short duration—one hour or less. While such investigations may throw light on certain isolated points in connection with the chemical changes in the body, it must be said that any conclusions drawn from them, applying generally to the heat phenomena of the animal, are untrustworthy. This becomes apparent when we consider the nature of the chemical changes productive of heat which go on in the body.

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* It is interesting to note that among physicists and chemists one sometimes meets the spelling *calory* and the pronunciation *calóry* or *căl′ory*. Among physiologists the original spelling *calorie* is retained (this statement is made after consulting all the available textbooks of physiology), as is also the pronunciation *caloree′* in conformity with the spelling and older pronunciation. Lexicographers seem to prefer the spelling *calory*, but give both *calory* and *calorie* as correct.

† Since the specific heat of water varies at different temperatures, this would be more accurately stated as the amount of heat required to raise 1 gm. of water from 15° C. to 16° C. See Berthelot, "Thermochimie," Paris, 1897, vol. ii., p. 5.

‡ When very minute quantities of heat are to be measured, the micro-calorie is sometimes used. A micro-calorie is .001 small calorie.

* "Mem. de l'Acad. des Sciences," 1777, p. 183.

† Op. cit., 1780, p. 355.

The greatest amount of heat made in the body is produced by the oxidation of food, which is prepared for absorption by the digestion processes and then carried by the blood to the lymph which bathes the cells of the different tissues. These living cells then slowly burn the combustible parts of the food, and throw the waste products back into the lymph surrounding them, from which the said waste products are taken up by the blood and carried to different organs for removal—the excreting organ depending on the character of the waste. The food which is thus burned consists mostly of carbon, hydrogen, and nitrogen, with a certain amount of oxygen, but not enough to cause its complete combustion, so that to burn it, as is done in the cells, requires the use of a considerable quantity of the oxygen which we breathe. It must not be forgotten, however, that the oxygen in the food itself is just as potent as the oxygen we breathe for forming oxidized waste products. So it is clear that unless we know how much oxygen the food contains we cannot use the oxygen taken up in the lungs as an accurate measure of oxidation.

Again, it is a well-known law in chemistry that when a highly complex molecule breaks down into more stable ones, there is a certain amount of energy liberated, and this energy is apt to take the form of heat. Now the food contains a large number of these highly complex molecules which break down into simpler ones and give rise to heat. The oxygen in the food is in different combination in different kinds of food, and the same oxidized end-product of the breaking down of one food may represent a very different amount of heat from that which it represents in another. This has a direct bearing on the "heat equivalent" of different food-stuffs.

From the above it must be seen that a determination of part or even all the oxidized waste products will not give satisfactory data from which to calculate the heat produced in the body, if the waste products alone are taken into consideration.

Some experiments have been made in which calculations of the heat produced have been made only from the CO_2 excreted. It is true that of all the elements of the food whose oxidation gives rise to heat, carbon is the most important, and it is also true that CO_2 is the chief waste product of such oxidation. It must further be granted that the amount of CO_2 given off by the lungs forms a rough and general index to the total amount of oxidation in the body, but this method is unreliable as a quantitative measure of heat produced, chiefly for the following reasons:

(*a*) There is always more or less carbon in food which is not oxidized all the way down to CO_2, but stops at intermediate stages. The amount of carbon thus incompletely oxidized varies under different conditions which are not easy to control or to recognize. This partial oxidation gives rise to heat, and there is no CO_2 to show for it.

(*b*) The oxidation of the hydrogen in food gives H_2O as its end product. The amount of heat thus produced is considerable, and there is no CO_2 to show for it.

(*c*) The amount of CO_2 thrown off by the lungs depends to a large degree upon the depth of respiration, owing to changes in the partial pressure of CO_2 in the pulmonary alveoli. With shallow respiration an animal can store up a large quantity of CO_2 in the blood, and give this off if the respiration becomes deeper, so that for experiments of short duration a very considerable error may be introduced simply by the animal changing the depth of its breathing.

(*d*) The condition of an animal, with regard to food, has a profound influence on both the heat produced and the CO_2 excreted, but they do not vary quantitatively together. This is shown by the following table compiled by Rosenthal* from the experiments of Senator and Liebermeister:

Animal in Senator's experiments.	Calories of Heat Produced per Hour.	
	Measured by calorimeter.	Calculated from CO_2.
Dog A, fasting	12.6	11.2
starving	10.9	10.4
during digestion	18.9	16.0
Dog B, fasting	16.5	14.1
during digestion	19.4	15.4
Dog C, fasting	16.9	10.4
starving	15.3	9.6
during digestion	22.0	12.2

It may be seen at a glance that the difference between the amount of heat measured directly by the calorimeter and the same value calculated from the CO_2 is considerable, and that this difference varies with the food. The figures in the table are for one hour only, so that the error for a day might be twenty-four times as great.

Indirect calorimetry becomes accurate only when a careful analysis is made and the temperature recorded of everything (food, drink, air, moisture, etc.) which enters the body (ingesta); and the same is done for everything which leaves the body (egesta). The difference between the potential energy of the ingesta and of the egesta will represent the energy which the body availed itself of, and temperature records of the body will show how much of this has taken the form of heat. Such observations are excessively laborious—far more so than direct calorimetry. When made in connection with direct calorimetry, however, they are exceedingly valuable, and to such experiments we owe one of the most important discoveries in modern science, viz.: that the human body obeys the law of the conservation of energy just like an inanimate machine—or, in other words; the fundamental laws of physics and chemistry dominate vital phenomena with all the rigor that they exercise in the inorganic world.†

Nearly all experimenters in the field of indirect calorimetry have employed modifications of the apparatus used by Regnault and Reiset,‡ or by Voit,§ in the classical researches of these authors. For an excellent *résumé* and criticism of this work, with references to original papers, the reader is referred to an article by Zuntz on "Respiratory Exchanges" in Hermann's "Handbuch der Physiologie," Leipsic, 1880, vol. iv., part 2, pp. 118–129.

§ 3. Direct Calorimetry.—Direct calorimetry consists in placing the body emitting heat in an appropriate apparatus (calorimeter) which will measure the amount of heat given off.

Two widely different classes of observations in the field of calorimetry are of interest to us in medicine. The one relates to the heat equivalent of foods, or, in other words, to determining the value of the different food-stuffs as energy-producers in the body; the other relates to the study of the animal body itself by means of the calorimeter.

Each class of researches demands different methods and different instruments. Those of the former class will be briefly touched upon here, while those of the latter will be more fully described.

The older method of determining the heat equivalent of a given food was to dry it carefully and then mix a known quantity of it with some chemical which would furnish oxygen, such as nitre or a mixture of potassium chlorate and manganese dioxide. This made a sort of gunpowder, which was detonated in a closed vessel surrounded by water, and the heat given off was measured by the rise in temperature of the water.

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* Rosenthal, "Hermann's Handbuch der Physiologie," 1880, vol. iv., part ii., p. 374.

† To be strictly exact, it must be said that the experiments in question have come up to ninety-nine per cent of absolute accuracy. Considering the complexity of the experiments and the probable error involved, this is sufficiently close to warrant the above statement. For a fuller discussion of this interesting question the reader is referred to Rubner, "Calorimetrische Methodik," Marburg, 1891; Rubner, "Die Quelle der thierischen Wärme," Zeitschrift für Biologie, 1893; Rosenthal, "Calorimetrische Untersuchungen," Arch. für Physiologie, 1894 and 1897; Atwater and Rosa, "A Respiration Calorimeter," etc., "Report of Storrs (Connecticut) Experiment Station," 1897; and Atwater and Rosa, and Rosa, "Physical Review," 1899 and 1900.

‡ Regnault and Reiset, Ann. de chim. et de phys., 1849, (3), xxvi.

§ Voit, Zeitsch. f. Biol., xiv., p. 122.

An improved method, suggested by Frankland, was first practically applied by Berthelot in a special calorimeter which he devised. This is known as the bomb calorimeter, and is made so as to contain the food to be investigated, with oxygen at a very high pressure (seven to twenty-five atmospheres). The food is ignited by means of a platinum spiral heated white hot by an electric current. Berthelot found that in such an atmosphere the food was completely oxidized. The bomb is immersed in water, and the heat given off is estimated from the rise in temperature of the water. There are many forms of calorimeters used for such determinations, but one of the two principles here outlined is at the bottom of all of them.

These methods give accurate and valuable results. They are applied not only to studying the heat equivalent of foods, but are also used to determine the heat equivalent of partially oxidized waste products from the body, such as urea. It must not be forgotten that we utilize only part of the potential energy of many of our foods, so that to rate the value of different foods as directly proportional to the figures in tables giving their heat equivalents would be a grave error. We are sufficiently acquainted with the metabolism of most of them to make a fair estimate of their true value as energy liberators in the body, but an adequate discussion of that question would be too voluminous to be attempted here.

Turning our attention now to the subject of direct calorimetric observations on animals, we may describe the process as follows: An animal is placed in one of the forms of calorimeter to be described in § 4, and the heat given off from the animal is determined in calories. This is known as the heat dissipated. If the temperature of the animal is the same on entering and on leaving the calorimeter, the heat produced must just equal the heat dissipated, for the animal brings out with his body just as much heat as he took in, and the heat dissipated while in the calorimeter must be exactly equal to what was produced there. If the temperature of the animal is higher on leaving than on entering the calorimeter, it shows that in addition to the heat dissipated and recorded by the calorimeter, there was an extra amount formed sufficient to raise the temperature of so much weight of animal so many degrees. In accordance with the laws of physics this extra amount may be found by the following formula:

$x = wdh$. In which—

x = the extra heat formed and not recorded by calorimeter.

w = weight of animal.

d = the difference in the animal's temperature between entering and leaving the calorimeter.

h = specific heat of animal's body.

The total heat produced is then found by adding the value of x to the amount of heat dissipated.

If the temperature of the animal falls while in the calorimeter, it shows that the heat dissipated and recorded by the calorimeter represents not only the heat actually produced by the animal while in the instrument, but also a certain amount of heat which is represented by the cooling down of so much weight of animal through so many degrees. In this case we must subtract the amount of heat found by the above formula from the amount of heat dissipated and recorded by the calorimeter, to get the true amount of heat produced during the time of the experiment.

Direct calorimetry furnishes the most reliable means of studying variations of heat production in the body, and by this method, and this method only, can we solve a number of interesting problems, notably those connected with fever. The temperature alone is a very unsafe guide. It has been shown over and over again, by direct experiment, that we may have high fever, while the animal or man is producing *less* heat than normal, and it has been shown, also, that certain antipyretics will lower the temperature while the production of heat in the body is far above the normal.

The temperature of the body depends upon two factors, and may be influenced by either of them separately or by both together. These factors are heat production and heat dissipation. In warm-blooded animals the balance is arranged so as to keep the temperature constant. If more heat is produced, for any reason, there is a corresponding increase in heat dissipation so that the temperature remains about the same. If more heat is dissipated more heat will be produced so as to keep the balance even and the temperature constant. If the balance is disturbed, as during fever, it is clear that we cannot tell in which factor the trouble lies by such an instrument as the thermometer, which only records the balance between them. These questions will be discussed more fully in the later sections of the article, and are only introduced here to show the importance of direct calorimetry in medicine.

Some of the objections urged against experiments of short duration in indirect calorimetry will also apply to direct calorimetry. The metabolism of the body is bewilderingly complex, and transient commotions produced by causes beyond the observer's perception may give results which would be totally inapplicable to calculation of averages, and which multiplied by the time sufficient to extend them to days would lead us to serious errors (see p. 559).

§ 4. DESCRIPTION OF CALORIMETERS EMPLOYED IN CLASSICAL MEDICAL RESEARCHES.—As the study of the heat equivalent of foods is usually taken up with chemistry rather than with medicine, and as the field is large enough to make a monograph by itself, it is deemed advisable to omit here a description of the apparatus and methods employed in this line of research. Those interested will find an excellent treatise on the subject in Atwater's "Methods and Results of Investigations on the Chemistry and Economy of Food" (U. S. Dept. of Agriculture, Bulletin No. 21, 1895).

The fundamental object of all calorimeters, for animals, is to register the amount of heat given off by the animal placed within them. This is done in different ways in different instruments, and the various kinds of calorimeters may be classified, according to the means used to measure the heat, as follows:

(*A*) Fusion (ice) calorimeters. In these the heat is made to melt some solid (usually ice), and the amount of heat is calculated from the quantity of the substance melted.

(*B*) Vaporization calorimeters. In these the heat is made to volatilize a liquid, and the amount of heat is measured by the quantity of liquid volatilized.

(*C*) Water calorimeters. In these the heat is taken up by water, and measured by different methods according to the instrument.

(*D*) Air calorimeters. In these the heat is taken up by air and measured by different methods, according to the instrument.

(*E*) Respiration calorimeters.

Each accurate calorimeter, whatever its form, must be calibrated. This is done by producing within it known quantities of heat, approximating those it will later be used to measure, and noting how accurately (and sometimes how rapidly) the calorimeter will register this heat. The known quantity of heat is usually produced by burning, within the calorimeter, a given quantity of hydrogen, alcohol, or some pure oil, or by passing an electric current of known strength through a coil of known resistance. The heat produced is calculated from the formula:

$\mathrm{H} = \mathrm{I}^2 \times \mathrm{R} \times k$.

In which H = the heat produced, I = the strength of the current in amperes, R = the resistance of the wire in ohms, and k is a constant, which, to give the value in calories per hour = .864.

This is the latest and most accurate method, and serves admirably to give varying amounts of heat through the range in which the calorimeter would be called on to register the heat of animals, including man.

Class A: Fusion Calorimeters.—The only calorimeter of this class employed in animal calorimetry was the ice calorimeter of Lavoisier and Laplace.[*] It consisted of three metal cylinders, placed one within the other, with spaces between them. The animal (guinea-pig) was placed in the innermost cylinder, and the space between this and the middle cylinder was filled with ice, which was melted by the heat given off by the animal. The space between the middle cylinder and the outer cylinder was also packed with ice to prevent heat from the outside from reaching the ice in the space next the animal cylinder. The water from the ice melted by the animal was collected and weighed and the heat calculated by multiplying this weight by the latent heat of fusion.

This is a very accurate form of calorimeter, but it is not well adapted to animal experiments, as the animal is kept in surroundings of an abnormally low temperature, and this seriously affects its production and dissipation of heat. The researches of Lavoisier and Laplace are classical, in being the second to employ the calorimeter, and the first to give valuable results of extended observations which were stated in terms of the modern combustion theory. In these experiments the animal was furnished with air, and the O used and the CO_2 given off were determined.

Class B: Vaporization Calorimeters.—Calorimeters of this class were used by I. Rosenthal and by Neesen.[†]

I. Rosenthal[‡] devised a calorimeter in which he used a fluid with a boiling point near that of the ordinary room temperature, or a fluid with a boiling point a few degrees below the normal temperature of the animal. The fluids which he recommends are acetic aldehyde, CH_3CHO, with a boiling point of 21° C., and ethyl ether, $(C_2H_5)_2O$, with a boiling point of 34.9° C.

The calorimeter consisted of an inner cylinder, in which the animal was placed, and an outer cylinder containing the liquid to be volatilized. The whole was surrounded by a water bath kept carefully at the temperature of the boiling point of the liquid in the outer cylinder. Thus no heat could either be gained or lost by the liquid in the outer cylinder except such as came from the animal in the inner cylinder. The heat from this source was all spent in volatilizing the aldehyde or the ether, and from the quantity thus volatilized the amount of heat given off by the animal could be determined. By filling the outer cylinder with ice the instrument could be used as an ice calorimeter, and thus, as Rosenthal pointed out, according to the material used the heat dissipated could be determined for temperatures of 34.9°, 21°, or 0° C. by the same apparatus. This calorimeter, as constructed, could be used only for small animals, such as mice, or for isolated organs, such as muscles.

Class C: Water Calorimeters.—The water calorimeter was the first employed in animal calorimetry (see account of Crawford's researches, § 1). From that time (1778) to the present it has been the favorite form. After Crawford it was used in the classical researches on animal heat by Despretz,[§] and by Dulong,[‖] and on fever by Senator,[¶] and by Wood.[**]

In its simplest form, a water calorimeter consists of a tank containing a definite amount of water into which is plunged a water-tight metal box containing the animal. The animal is supplied with air by tubes entering and leaving the box. The heat given off by the animal raises the temperature of the water, and, knowing the weight of the water and the increase in temperature, the amount of heat thus given off can be calculated in calories. In text-books, the calorimeter of Dulong is generally described, but in the present article the Reichert calorimeter is chosen as a type of this class. This instrument combines all the simplicity of the older forms with the accuracy and convenience of modern improvements. It has been used by Reichert[*] in his researches on animal heat, on fever, and on drugs.

The calorimeter consists of a metal box *A*, for the animal, and a larger metal box surrounding the box *A*, the space between the two metal boxes being filled with water. The whole is enclosed in a wooden box, the space between the outer metal box and the wooden box being filled with shavings *SH*, to prevent the radiation of heat. At the right of the figure is an opening from the exterior into the box *A*. This is for putting in and taking out the animal. During the experiment it is closed by a wooden plug fastened with clamps to the wooden box. The tubes *EN* and *EX* are for the entrance and exit of air, and each is furnished with a thermometer as shown in the figure. Another thermometer, *CT*, registers the temperature of the water. *S* is a stirrer to mix the water thoroughly so as to be sure that the temperature recorded is the temperature of the whole mass of water. The arrows show the direction of the air current through the animal box.

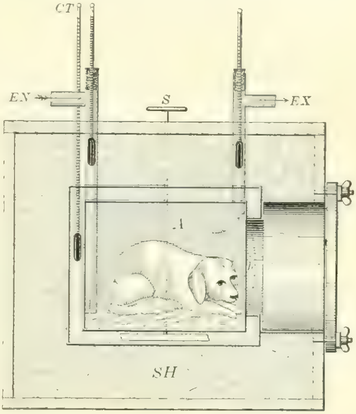

FIG. 1073.—Reichert's Water Calorimeter.

Ott[†] devised a water calorimeter of sufficient size to take a man. The inner chamber, to receive the patient, was cylindrical in form, and the air, as it was drawn from this chamber, passed through a lead pipe coiled in the water and thus gave off its heat to the water. The water was slowly stirred by a mixer driven by an electric motor.

D'Arsonval's compensating calorimeter, of constant temperature, is another form of water calorimeter, although the principle involved in the measurement of heat is different from that of the calorimeter last described.[‡]

This instrument is shown in Fig. 1074. It consists of two cylinders, of thick copper, enclosing a space between them. Through this space run two spirals of metal tubing like the worm of a still. These spirals are shown in cross-section in the figure. One of these spirals connects the inner chamber of the calorimeter with the outside air. The air is aspirated through the calorimeter, passing in by a tube on the left, as shown by the arrow in the figure, and out, by the spiral, to the exterior. In passing through the spiral it gives up its heat to the petroleum with which the space between the cylinders is filled. The other spiral opens, at both its ends, on the exterior. It conducts a stream of cold water which is made to flow through it. The space between the copper cylinders, enclosing the spirals, is filled with petroleum because of its mobility. When the heat of the animal warms this petroleum it expands, and exerts pressure on the apparatus shown in the figure to the right of the calorimeter. This is arranged to control the flow of water through the cold-water spiral.

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[*] Lavoisier and Laplace, "Mémoires de l'Academie," Paris, 1780, p. 369.

[†] See Richet's "Dictionnaire de Physiologie," Paris, 1897, vol. ii., p. 405. The writer was unable to find a reference to Neesen's original article.

[‡] I. Rosenthal, Arch. für Physiol., 1878.

[§] Despretz, Ann. de chim. et de phys., 1824, vol. xxiv., p. 337.

[‖] Dulong, Ann. de chim. et de phys., 1843, p. 140. In 1822, the Paris Academy offered a prize for the best experimental researches on animal heat. Despretz and Dulong were competitors and Despretz won. The work of the two was contemporaneous, but Dulong's paper was not published until 1843, after his death.

[¶] Senator, "Untersuchungen über den fieberhaften Process," Berlin, 1873.

[**] Wood, "Smithsonian Contributions to Knowledge," No. 357.

[*] Reichert, University Med. Mag., 1890, vol. ii., p. 173, and "American Text-Book of Physiology," 1896, p. 586.

[†] Ott, New York Med. Journ., 1889, vol. xlix., p. 343; also Journ. Nerv. and Ment. Dis., 1890, vol. xvii., p. 348.

[‡] D'Arsonval, Arch. de Physiol., 1890, p. 612.

When the calorimeter is working this makes a sensitive, automatic regulator. If the temperature of the petroleum tends to rise the pressure exerted by its expansion causes more cold water to flow, and this immediately reduces the temperature of the petroleum to the point for which the instrument is set. (For a description of this regulator in detail, see *Arch. de Physiol.*, 1890, p. 614.) The cold water is furnished from a tank, and is made to enter the calorimeter at a known temperature. A tank filled with ice furnishing water at 0° C. is the arrangement recommended. The temperature of the water on entering the calorimeter, the temperature on leaving it, and the amount of water passed through being known, the amount of heat given off by the animal can easily be calculated in calories. It is found by experience that the water leaves the spiral through the petroleum at the temperature of the petroleum, and when this is kept at the room temperature, as it should be, the amount of heat given off by the animal is directly proportional to the amount of cold water required to keep the temperature of the petroleum constant. If, therefore, the amount of cold water flowing through the spiral be recorded continuously throughout the experiment, we can not only calculate the total amount of heat given off by the animal, from the beginning to the end of the experiment, but we can tell whether there was any variation in the rate at which this heat was given off, by finding, from the record, the variations in the rate with which water flowed through the spiral.

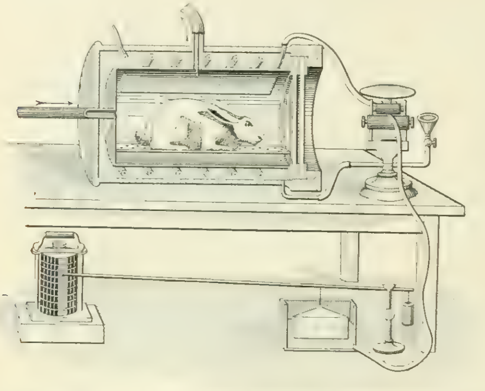
FIG. 1074. D'Arsonval's Compensating Calorimeter of Constant Temperature.

A simple form of apparatus for registering the flow through the spiral is shown in the figure as placed on the floor under the table. It consists of a cylinder (shown in section in the figure) which receives the outflow from the spiral. On the surface of the water is a float which rises as the water in the cylinder rises. This float is attached to a lever which has on its short arm a counterpoise weight for the float, while the long arm is made to write on a cylinder driven by clockwork. Since the rise of the lever is directly proportional to the amount of water flowing through the spiral, and since this is directly proportional to the heat given off by the animal, it follows that the ordinates of the curve written by the lever will be directly proportional to the heat which we wish to measure. The abscissas will be in terms of time, and will be proportional to the speed of the drum. By regulating the length of the lever and the speed of the drum a curve may be obtained which can be read in terms of calories for any convenient unit of time, minutes, hours, days, etc., without further calculation. A more elaborate recording apparatus with electrical contacts is figured and described by D'Arsonval (*Arch. de Physiol.*, 1890, p. 616). The same author has described a more convenient but less accurate calorimeter based on a modification of the one just described (*op. cit.*, p. 620).

One of the most recent, as well as one of the most elaborate and perfect water calorimeters, is that of Atwater and Rosa.*

In this calorimeter experiments, lasting several days, have been conducted on man.

The principle involved is practically the same as that of D'Arsonval's compensating calorimeter (Fig. 1074); the heat being removed by coils of pipe carrying cold water through the chamber where the man is placed. For a full description of this instrument and methods employed, the reader is referred to the original papers. A more condensed description of the apparatus is given under the head of Respiration Calorimeters at the end of this section.

Calorimetry by Baths. The study of heat phenomena in animals by baths has found a place in medical literature chiefly through the classical researches of Liebermeister,† and his pupils Kernig, Hattwig, and Gildemeister.

The method here employed was to place the patient in baths of different temperatures, and to calculate the production of heat from the gain or loss of heat by the patient and by the water under different conditions. This procedure presents certain crudities and sources of error which have been pointed out by nearly every special investigator in the field, but it has lately been defended by Lefevre,‡ who employed it in some experiments of his own. The researches of Lefevre are of interest in showing some interesting points as to the rapidity with which the heat-regulating mechanism adjusts itself when the patient is placed in a cold bath. They also show that this mechanism is neither as sensitive nor as efficient in an ape as it is in man, but they fail to convince one that the method is trustworthy for obtaining absolute values of heat dissipated or produced. Most of his observations were of short duration—five to twenty minutes.

Leyden§ employed the bath method in his researches on fever which are classical. In his experiments a part of the body, usually a leg, was immersed in water in an apparatus somewhat resembling a plethysmograph, and the heat given off to the water measured. In many of Lefevre's experiments the patient was placed in a sitz bath and only part of the body covered by water.

Class D: Air Calorimeters.—The first air calorimeter was used by Scharling.‖ This consisted of a closed box placed in a room of constant temperature. When a man was put in the box, the temperature of the air in the box rose, and from this rise the heat given off by the man was calculated. A calorimeter of practically the same principle was used in the early experiments of Vogel, of Sapalsky and Klebs, and of Hirn; and in the later researches of Kaufman,* who speaks of it as simple and precise.

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* Atwater and Rosa, "Report of Storrs (Connecticut) Experiment Station," 1897; also Atwater and Rosa, and Rosa, "Physical Review," 1899 and 1900.

† Liebermeister, Deutsches Arch. f. klin. Med., v., pp. 217-234; x., pp. 89 and 420; also "Handb. d. Path. u. Therap. des Fiebers," Leipzig, 1875, p. 197.

‡ Lefevre, Comptes rendus, Soc. de Biol., 1894-96.

§ Leyden, Deutsches Arch. f. klin. Med., v., p. 273.

‖ Scharling, Journ. f. practische Chemie, 1849, vol. xlviii., p. 435.

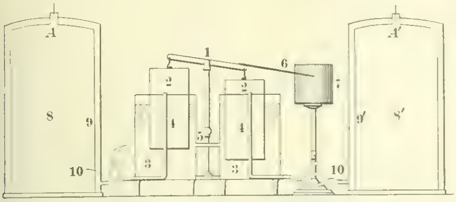

FIG. 1075. D'Arsonval's Differential Calorimeter.

In most of the later forms of air calorimeters, the principle of measuring the heat by a rise of temperature of the air has been discarded, and the expansion of air caused by the heat given off from the animal has been used as an index. This gives a more convenient and more delicate method of measurement.

One of the simplest calorimeters constructed on this principle is the siphon calorimeter of Richet.† This consists of two double-walled hemispheres of metal, fitting upon each other so as to make a globe. They are connected by a hinge, so that the upper hemisphere may be thrown back like the lid of a box. When closed they are fastened by an ordinary clasp. The air space between the two walls of each hemisphere is connected by a tube with a large bottle of water, arranged like a wash bottle, in such a way that when the air between the walls of the hemispheres expands it forces out a volume of water equal to the expansion of the air. When an animal is placed in the globular box formed by the two hemispheres, the heat given off by the animal causes the air to expand in the way just described. This expansion is measured by the amount of water forced out of the bottle, and the amount of heat given off by the animal is thus determined.

U. Mosso ‡ used a calorimeter constructed on the principle of the above. The water, forced out of the bottle, passes into a balanced recipient after the manner of the registering apparatus of Mosso's plethysmograph. This is an ideal arrangement, for a continuous graphic record can thus be kept of the rate of heat dissipation throughout the experiment, and if for any reason the animal should absorb heat, instead of giving it off, this would be recorded as well.

Differential Air Calorimeters. The principle involved in differential air calorimeters is to have one closed air space affected by the heat of an animal, while another similar air space is kept at a constant temperature. These air spaces are connected with an appropriate recording apparatus, and the heat given off by the animal is calculated from the difference in expansion of the two.

The simplest form of differential air calorimeter is D'Arsonval's § compensating differential calorimeter, shown in Fig. 1075.

This instrument consists of two calorimeter chambers 8 and 8′. Each of these chambers has a double wall enclosing an air space, 9 and 9′. These air spaces are connected by a rubber tube, 10 and 10′, with the registering apparatus. This consists of a lever balance, 1, from each arm of which is suspended a cylinder, 2 and 2′, closed at the top, the lower end dipping into tanks of fluid, 3 and 3′. These tanks are connected by a tube, 5, so that the level of liquid is the same in each. The tubes, 4 and 4′, rise above the surface of the liquid. When the air in the space 9 or 9′ expands it passes into the cylinder 2 or 2′ respectively, and buoys this cylinder up, thus raising the arm of the lever 1. To one arm of the lever is attached a straw, 6, terminating in a writing point which records on a cylinder, 7. This cylinder moves by clockwork, and can be made to go so slowly that continuous records of a day or a week may be obtained.

When an animal is introduced into one of the calorimeter chambers, 8 or 8′, the heat given off causes the air in 9 or 9′ to expand, and this expansion is registered as above described. The empty calorimeter chamber is under exactly the same conditions except for the presence of the animal, and registers on the opposite arm of the lever, thus giving a *compensating* effect for the instrument minus the animal. The curve recorded is due to the *difference* which is produced by the animal, and is independent of barometric changes, room temperature, etc.

This instrument is classical and is often referred to. It is theoretically excellent, but it possesses practical disadvantages which render it unfit for accurate scientific research, as the writer has found from personal experience (see also D'Arsonval, *Arch. de Physiol.*, 1890, pp. 787 and 789).

The most complete and accurate air calorimeters are those of Rubner* and of Rosenthal.† These eminent investigators have spent years in perfecting their respective instruments, and each, notably that of Rubner, has been used in extensive and valuable researches. These calorimeters are too elaborate to be described in detail here. A complete description of the latest improvements will be found in the original papers of Rubner and Rosenthal referred to above.

The fundamental principle of these two calorimeters is the same. Each consists of two closed air spaces, one of which is warmed by the heat from the animal, while the other is immersed in a bath which is kept at a constant temperature by an automatic regulator. Rubner measures the expansion of the air by an apparatus similar in principle to that employed by D'Arsonval and shown in Fig. 1075. Rosenthal connects the two air spaces, respectively, with a U-manometer, which will respond at once to any difference of pressure on the two sides. Connected with the air space on one side, there is an ingenious piston arrangement by which air can be forced in, so as to make the pressure on the two sides of the manometer equal. This is driven by an electrical device which is set in motion the moment the liquid in the manometer changes level. The amount of pressure thus exerted is registered automatically, so that a complete graphic record may be kept of how much pressure was necessary to equalize exactly the pressure exerted by the air expanded by the heat from the animal, and thus this heat may be calculated.

Haldane White and Washburn ‡ have described a compensating differential air calorimeter in which the animal is placed in one side while a hydrogen flame is kept burning in the other. The enclosed air spaces of the two sides are connected with the opposite arms of a manometer. The hydrogen flame is so regulated that it shall give off exactly as much heat as the animal, as shown by the liquid in the two branches of the manometer remaining at the same level. The amount of hydrogen burned is estimated and the heat produced by the flame calculated. This exactly equals the amount given off by the animal, since the heat produced in each calorimeter chamber is the same.

Anemo Calorimeter of D'Arsonval. § Most of the calorimeters above described are cumbersome, many are suitable for experiments on small animals only, and none of them can be conveniently adapted to the clinical study of fever in the hospital. To obviate these disadvantages D'Arsonval attacked the problem of devising a calorimeter which should fulfil the following conditions:

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* Kaufman, Comptes rendus, Soc. de Biol., 1896, p. 201.

† Richet, Comptes rendus, Soc. de Biol., 1884, pp. 707-715; also Arch. de Physiol., 1885, vol. vi., p. 237.

‡ Mosso, Arch. Ital. de Biol., 1890, vol. xiii., pp. 467-471.

§ D'Arsonval, Arch. de Physiol., 1890, p. 785.

* Rubner, "Calorimetrische Methodik," Marburg, 1891; also "Die Quelle der thierischen Wärme." Zeitsch. f. Biol., vol. xxx., 1893-94, pp. 73-142.

† Rosenthal, "Calorimetrische Untersuchungen," Arch. f. Physiol., 1897, pp. 170-209.

‡ Journ. of Physiol., 1894, vol. xvi., p. 127.

§ D'Arsonval, Arch. de Physiol., 1891, p. 364.

"1. To be set up in any room in a hospital.

"2. To be light and easily portable.

"3. To allow the calorimetric observation to be made rapidly—say in five minutes.

"4. To be set up over the bed of a patient and give automatically continuous records in the form of a curve without requiring the presence of some one to watch the apparatus."

The calorimeter which, he claims, meets all these requirements is shown in Fig. 1076.

The principle of the calorimeter is very simple. The heat of the body causes the air to rise. This creates a current which passes through the chimney and sets the anemometer vane revolving. The more heat, the stronger the current and the more rapid the revolution of the vane.

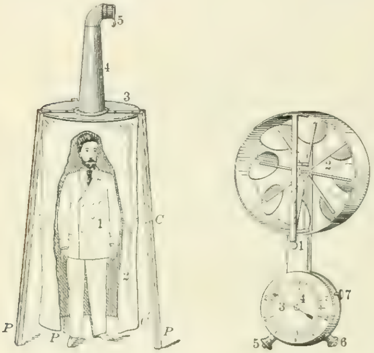

FIG. 1076.   FIG. 1077.

FIGS. 1076 AND 1077.—D'Arsonval's Anemo-Calorimeter.

FIG. 1076.—Calorimeter. Description: 1, The subject of the experiment; 2, cylinder of woollen stuff fixed to a disc of wood, 3, and kept from collapsing by the hoops C and C; part of the cylinder is cut away to show the subject; 4, conical chimney bent near its end; 5, opening of chimney with anemometer attached. The anemometer is shown, on a large scale, to the right (Fig. 1077).

FIG. 1077.—Anemometer. Description: 1, Lever for throwing the vane in connection with the recorder; 2, vane composed of eight aluminum fans; 3 and 4, hands of recorder; 5 and 6, binding posts for wires to odograph; 7, button for putting the hands back to 0.

The heat given off was found to be directly proportional to the square of the number of revolutions of the vane in a unit of time.

Each instrument has to be graded separately by placing in it some source of heat which gives off a known quantity in a given time. It can then be calculated how many turns of the vane represent a given number of calories. The numbers are convenient for calculation; for example, in D'Arsonal's own instrument eighty revolutions per minute represent 21.6 great calories per hour.

One would hardly suppose, *a priori*, that such a crude arrangement would give accurate results, but the figures obtained by D'Arsonval while calibrating it would seem to leave no doubt as to its reliability. As a source of heat he employed a ferro-nickel spiral heated by an electric current. The error in the record of the anemometer was 2 revolutions in 2,400, and 5 in 3,600, so that it was practically exact.

The instrument has no time-loss in recording. Within one minute from the time a man enters the calorimeter the vane has attained its maximum velocity, and two minutes after this suffice for an observation, so that a whole experiment can be made in three minutes—a desideratum often important in clinical work.

The accuracy of the records of the anemo-calorimeter is independent of the room temperature. The vane revolves from a current of air which depends upon the difference in temperature between the air entering and the air leaving the calorimeter. This *difference* is constant for the same source of heat whatever may be the temperature of the air entering, *i.e.*, the temperature of the air of the room.

In his laboratory, D'Arsonval uses a wooden box with a glass door instead of the woollen curtain, of the portable form, shown in the figure.

Laulanie* used an anemo-calorimeter, and found that the heat produced runs closely parallel with the oxygen consumed.

When it is desired to make observations continuing for a considerable time, the apparatus is connected with a Marey odograph,† and the record is taken on a revolving cylinder. With the calorimeter thus arranged over his own bed, D'Arsonval made observations on himself during sleep.

Class E: Respiration Calorimeters.—A respiration calorimeter is one which is so arranged that the air taken in, and the air breathed out, by the animal can be analyzed; in other words, it is one which permits observations to be made by the method of indirect calorimetry and of direct calorimetry at the same time.

Nearly all the water calorimeters and air calorimeters have been arranged in this way. The most elaborate instrument of the kind is one recently perfected by Atwater and Rosa (see Water Calorimeters) with the assistance of funds supplied by the United States Department of Agriculture, and of the State of Connecticut. The description here given of this calorimeter is taken (condensed) directly from one of the papers by the original authors.‡

"*The Apparatus.*—The name here used for the apparatus, 'respiration calorimeter,' is suggested by the fact that it is essentially a respiration apparatus with appliances for calorimetric measurements. As a respiration apparatus it is similar in principle to that of Pettenkofer. The calorimeter is essentially a water calorimeter, that is to say, the heat evolved in the chamber is measured by a current of water. The appliances for measurement of both the respiratory products and the heat given off from the body differ in some important respects from those of any other apparatus with which we are familiar.

"The apparatus includes, first of all, a room or chamber in which the subject remains during the experiment. The chamber is furnished with a folding chair and table for the man's use during the day, and a folding bed on which he sleeps at night. When the experiments involve muscular work, a stationary bicycle, especially arranged for measuring the work done, is also introduced. Light enters through a window so that the occupant can see to read and write. Ventilation is provided by a current of fresh air, maintained by a pump specially devised for the purpose. This pump not only keeps up a constant current of air, but also measures its volume and withdraws samples regularly and accurately for analysis. The air is made to enter the chamber at the same temperature as when it goes out, so that the quantities of heat brought in and carried out by this ventilating current are the same. Arrangements are provided for passing food and drink into the chamber and for removing the solid and liquid excreta. Arrangements described beyond prevent the passage of heat through the walls of the apparatus.

"The heat given off from the body is carried away by a current of cold water which passes through a series of pipes inside the chamber. Houses are warmed in winter by a current of water which is heated in the basement of the house, and passes through pipes and radiators in the different rooms. The heat thus radiated from the water into the room keeps the air of the latter at the de-

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* Laulanie, Comptes rendus, Soc. de Biol., 1896, p. 5.

† Marey, "Methode graphique," Paris, 1878, p. 183.

‡ Atwater and Rosa, "Report of Storrs (Connecticut) Experiment Station," 1897.

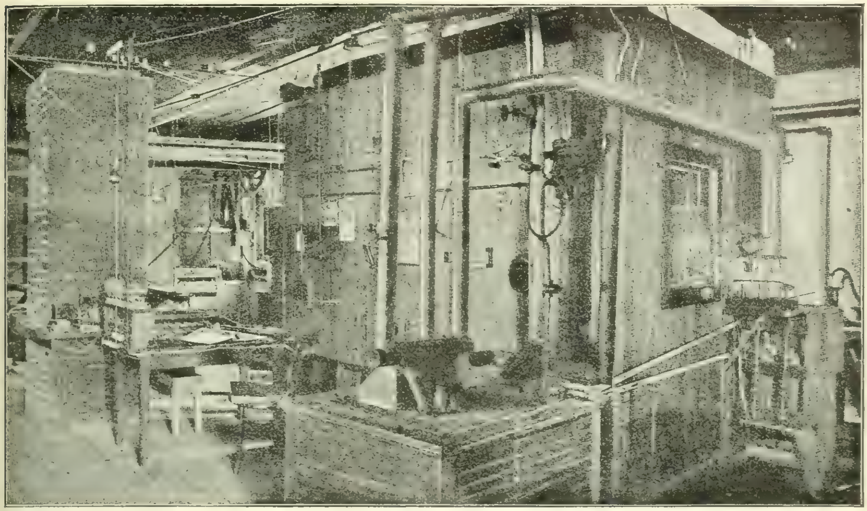

Fig. 1078.—Respiration Calorimeter. General view.

sired temperature. In like manner the house might be cooled in summer by a current of cold water. In this case the radiators would become absorbers. The heat would be taken up from the air of the room by the cold water and carried away. Exactly this is done by the absorbers inside the chamber of the respiration calorimeter. By regulating the temperature of this water current as it enters, and also its rate of flow, it is possible to carry away the heat just as fast as it is generated, and thus maintain a constant temperature inside the chamber.

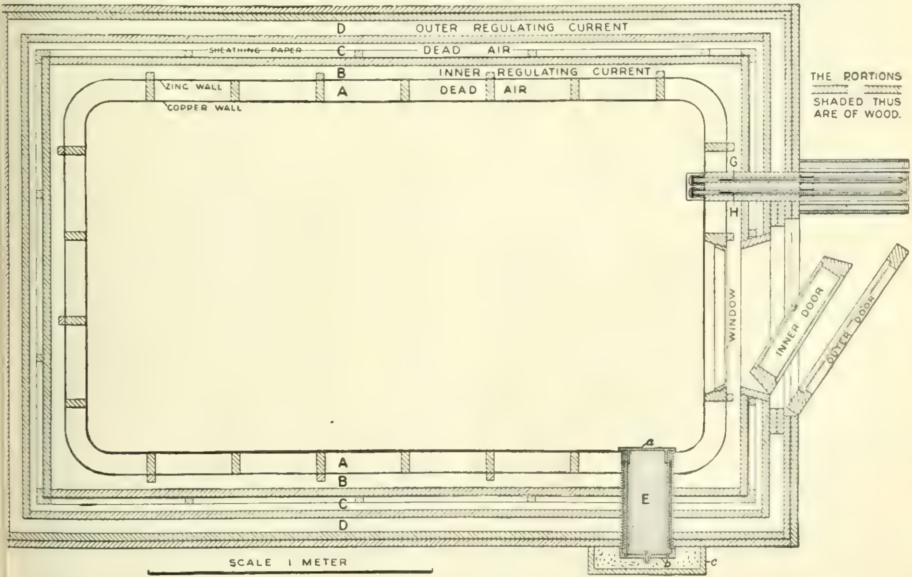

Fig. 1079.—Horizontal Cross-Section of Respiration Calorimeter.

The amount of the outgoing water and its temperature are measured, thus determining the heat carried away.

"A general idea of the apparatus can be had from Figs. 1078 and 1078. Fig 1078, from a photograph, is a general view of the principal parts of the apparatus, though the pump and aspirators used for moving, measuring, and sampling the ventilating air current and the refrigerating machine are not shown. In the centre is the large chamber which is surrounded by sheathing of wood. At the end of the chamber, on the right, is shown a glass door which serves also as a window. In the foreground, near the centre and at the right, are the pipes through which the ventilating current of air passes. At the right of the window and just below it are the arrangements for cooling and for measuring the current of water which brings away the heat from the interior of the chamber. At the left, in front of the large brick pillar, is a table at which an observer sits to record the temperature of the interior of the apparatus and of the currents of air and water, these temperatures being measured by electrical thermometers. Behind the brick pillar is the refrigerating machine, not shown in the picture. The object of this is to cool the brine, *i.e.*, a solution of calcium chloride contained in a large tank in the centre foreground. The tank is surrounded by a wooden casing. The ventilating current of air, before it enters the chamber, is passed through copper cylinders which are immersed in brine in this tank, and thus cooled to a temperature of from −19° to −22° C., or from −2° to −8° F. At this very low temperature nearly all the water is removed from the air, so that it enters the chamber quite dry. Just before entering, at the right of the glass door, it is warmed to the temperature of the interior of the chamber. On coming out it passes once more through copper cylinders in the cold brine, and thus the larger part of the water which has been imparted to it by the respiration of the man inside the chamber is frozen and removed. The air pump is at the right and the aspirators are at the left of the position occupied by the camera in taking the photograph

"*The Respiration Chamber* —The internal construction of the chamber and the arrangements for regulating the temperature are shown in horizontal section in Fig. 1079.

"The chamber proper is practically an apartment with double walls of metal, the inner wall being of sheet copper and the outer one of zinc. The interior is 2.15 m. (7 ft.) long, 1.92 m. (6 ft. 4 in.) high, and 1.22 m. (4 ft.) wide, the corners being rounded. It thus has a little less than 28 square feet of floor space. The cubic content is not far from 4.8 cubic metres or 175 cubic feet. The inner wall is made of large sheets of copper, the seams being soldered so that when the windows and other openings are closed the chamber is air tight, and the only air which enters or leaves is that of the ventilating current. Outside this copper wall is one of zinc. Between the two metal walls is an air space (A) of 7.5 cm. (3 in.). In this space stands a wooden framework to which the two metal walls are securely attached. This metal chamber is the calorimeter proper. In order to protect it from the fluctuations of temperature of the room in which it stands, it is enclosed within three concentric walls of wood. Between the zinc and the innermost wooden wall is an air space (B) of 5 cm. (2 in.), between this wall and the next is a third air space (C) of 5 cm., and finally between this and the outer wall is a fourth air space (D), likewise of 5 cm. The wooden walls are made of matched pine covered with sheathing paper. The outer one is double with sheathing paper between. The air in the spaces A and C is 'dead air,' while that in the spaces B and D can be kept in constant circulation by means of rotary fans in boxes outside. Each of the spaces B and D is continuous around the sides and over the top and bottom of the calorimeter, and each communicates with its fan box by means of one passage extending from the top of the air space to the top of its fan box, and another from the bottom of the air space to the bottom of the fan box. We may thus look upon these air spaces as shields guarding the interior space occupied by the calorimeter from changes in temperature without. They thus render necessary aid in accomplishing a fundamental object, namely, the keeping of the temperature of the air in the space B the same as that of the interior of the chamber. When these temperatures are the same there will be no passage of heat through the walls, either into or out of the chamber.

"The outer air current (D) is used for the coarser regulations of temperature. In the middle of the dead air space (C) is a wall of sheathing paper intended to more effectually prevent the external temperature from affecting that of the calorimeter.

"The walls are provided at the right with glass doors or windows. At E in Fig. 1079 is a cylinder of copper which passes through the walls of the chamber and also through the encasing walls of wood. This cylinder, which is 15 cm. (6 in.) in diameter, serves for passing food and other materials into and out of the calorimeter chamber, and is here called the 'food aperture.' It is closed at the ends by caps *a* and *b*. The outer (*b*) is screwed tightly to the cylinder so as to make an air-tight closure. Outside of this is a box or cover (*c*), made of wood and filled with cotton or other non-conducting material, the purpose being to prevent the passage of heat through E.

"*Measurements of Temperature.* The measurements of temperature are made in part by mercury thermometers, but mainly by electrical methods. The electrical measurements of temperature are made by use of either the German silver-iron thermal junctions or by resistance coils of fine copper wire. Provision is made for connecting these with a D'Arsonval galvanometer especially constructed for the purpose by Mr. O. S. Blakeslee, mechanician of Wesleyan University. The electrical thermometers permit measurements of .01° C. or less.

"*Temperature of Air Inside the Chamber.* Inasmuch as the temperature of the air is not the same in different parts of the chamber, and it is desirable to know the average or resultant temperature of the whole, the attempt is made to learn the latter by the use of a series of five electrical thermometers at places near the sides, top, and bottom. These consist of resistance coils of copper wire connected with a slide wire Wheatstone bridge and the galvanometer outside. The measurements are so delicate that even slight movements of the person inside, such as rising from the chair, reveal themselves to the observer outside by the immediate rise in the thermometric reading.

"*Regulation of Temperature of Ingoing Air.* In order that the ventilating current of air shall not carry out of the chamber any more or any less heat than it brings in, the temperature must be the same when it enters as when it leaves. Accordingly the incoming air, which leaves the brine tank at a very low temperature, is warmed, before its entrance to the chamber, to the temperature of the outgoing air. The devices for this purpose are such that the difference of temperature of the incoming and outgoing currents can be kept inside of .01° C. In actual experiments the positive and negative differences are made to counterbalance each other.

"*Arrangements for Preventing the Passage of Heat through the Walls of the Calorimeter.* The difference between the temperature of the copper wall and that of the zinc is measured by a system of thermo-electric junctions, in three hundred and four pairs, distributed over the sides, top, and bottom, one-half of the junctions (iron-German silver) being in close thermal contact with the copper wall and the other half (German silver-iron), with the zinc wall. The difference of temperature of the two walls is made as small as possible by warming or cooling the air in the space B, and the positive and negative differences are made to counterbalance each other. Thus the corresponding movements of small quantities of heat inward and outward also counterbalance, and the chamber neither gains nor loses heat through the walls.

"For the measurement of the differences of temperature, as well as for the warming and cooling, the walls of the calorimeter are considered as divided into four sections, viz.: (1) the top; (2) the upper half of the sides or 'upper zone'; (3) the lower half of the sides or 'lower zone'; (4) the bottom. The systems of thermo-electric elements for heat measurements, wires for warming and of water pipes for cooling, are each divided into corresponding sections.

"*The Observer's Table.* This is shown in Fig. 1078 at the left, in front of the brick pier. A shelf fastened to the pier and shown on the right of the latter, behind the table in the picture, holds the galvanometer and scale. The scale is seen in the picture at the front end of the shelf over the table. The galvanometer is at the other end of the shelf, two metres from the scale and obscured by the pier. On the table are the switches to bring the various circuits into connection with the galvanometer, and with them the Wheatstone bridges, and the banks of electric lamps for varying the heating currents.

"With the aid of the devices thus briefly described an experienced operator at the observer's table can easily control the temperature of B and make it follow the variations of the interior of the chamber very closely. When the rate of generation of the heat in the chamber is reasonably uniform and the temperature is nearly constant, the deflection of the image on the scale at the observer's table can usually be kept within one division of the scale, which means an average difference of temperature between the copper and zinc walls of less than .01° C. In ordinary experiments the difference is generally kept within this limit and seldom reaches .05°. The differences are both positive and negative, and are easily made to counterbalance each other during shorter periods and during the whole experiment.

"*Measurement of the Heat Carried Out by the Water Current.* The principle here employed is simple. The chamber neither gains nor loses heat by the air current nor through the walls. The current of cold water which passes through the heat absorbers inside the chamber is caused to enter at a temperature generally but little above the freezing point, and to flow out at such a rate as to absorb and carry off the heat just as fast as it is generated inside the apparatus. The temperature of the water is measured as it enters and as it comes out. The mercury thermometers are shown at G and H in Fig. 1079. The electrical thermometer indicates the difference of temperature between the incoming and outgoing water currents by the difference of resistance of two coils of thin copper wire, of which one is in each pipe at the place of entrance or exit from the calorimeter. The difference is measured by a Wheatstone's bridge on the observer's table. The mass of water is measured automatically by the apparatus shown below and at the right of the window of the respiration chamber in Fig. 1078.

"From the mass of the water which has passed through the absorber in a given time, and the rise in temperature, the quantities of heat brought out are readily calculated. To this is to be added a certain amount of heat which is carried away with the water vapor produced in the apparatus. This is practically the difference between the water vapor in the incoming and outgoing air. From the amount of this vapor, and its latent heat at the temperature of exit, the amount of heat it carries out is easily computed.

"*Metre Pump for Regulating, Measuring, and Sampling the Ventilating Air Current.* For taking samples of air for analysis, aspirators of 150 litres capacity were employed at the outset and are still used. The measurements with these have been found quite accurate.* The most satisfactory arrangement we have found, and one which serves the threefold purpose of maintaining the air current, measuring its volume and delivering aliquot samples of convenient size for analyses, is an apparatus designed and made by Mr. O. S. Blakeslee, and appropriately designated by him as a 'metre-pump.' The air coming from the discharge pipe escapes into the room, but by a special device the air of each fiftieth stroke is diverted into a receptacle, from which it is being constantly drawn for analysis.

"*Cooling Apparatus.* It is desirable that the ventilating current of air shall enter the respiration chamber as dry as possible. To this end it is cooled to a temperature of −19° to −22° C. (−2° to −8° F.), by passing through copper cylinders which are immersed in brine in the tank shown in Fig. 1078. The brine is cooled by use of an ammonia refrigerating apparatus.* The air after passing out of the cylinder is warmed before entering the chamber in the way described. On coming out of the chamber the air current is again passed through copper cylinders immersed in the brine, and thus practically all of the water which has been imparted to it within the chamber is removed. The same brine is used for cooling the current of water which passes through the absorbers and conveys away the heat from the chamber.

"*Analyses of Air, Determinations of Carbon Dioxide and Water.* The methods used for these purposes are essentially the same as described in the 'Report of the Storrs Experiment Station,' and 'Bulletin 44 of the Office of Experiment Stations of the United States Department of Agriculture,' above referred to. It will therefore suffice to say here that the larger part of the water is caught in the copper cylinders, immersed in the cooling brine as above described, and its amount found by weighing. The residue of the water of both the incoming and outgoing air current is determined in samples by passing through U-tubes containing pumice stone and sulphuric acid. The carbonic acid is in like manner determined by passing through U-tubes containing soda lime.

"In the ordinary experiments the determinations of water, carbonic acid, and heat are made for periods of six hours."

§ 5. CALORIMETRY IN PHYSIOLOGY.—*Heat Centres.*—In § 3 it was pointed out that the temperature of the body depended upon the balance between two factors: heat production and heat dissipation. We know that heat dissipation is dependent chiefly upon three factors: the supply of blood to the skin, the sweat, and respiration. The more blood in the vessels of the skin the more heat will be radiated off; the more sweat formed the more heat will be lost by the temperature of the sweat and by evaporation; the more vigorous the respiration the more heat will be lost in the expired air and by evaporation in the air passages. Each of these functions is dominated by a special centre or set of centres, the vaso-motor, the sweat, and the respiratory centre, respectively. The question has naturally arisen, How is it with heat production? We know that the nervous system controls the chemical activities of the tissues—is there a centre which dominates this control? If so, how? Are there centres which cause an increased oxidation of food with increased production of heat? Are there centres which inhibit this oxidation and thus decrease heat production? Are there specific nerves through which such centres act on the tissues? It is in the experimental investigations relative to these questions that the calorimeter has been most employed in physiology.

The method of experiment has usually been to produce a lesion of the central nervous system, or to stimulate a definite area; and to note the effect on the animal's temperature, or to measure the effect on heat production and heat dissipation by direct or by indirect calorimetry.

It is obviously not within our province to undertake a critical review of all the work done on a specific subject, such as heat centres. Besides, our information is at present in a state more or less chaotic, as has always been the case with work of this kind on the central nervous system. We need only recall the confusion which existed fifteen or twenty years ago regarding experiments on "localization" in the cortex, of the centres of motion, and of the special senses, to get a fair idea of the present condition of our knowledge regarding heat centres. The outcome of it all has been that to-day practically no one denies the more or less definite localization in the motor area, but few would still adhere to the extreme views of invariable sharp localization of a given centre at a given spot, especially in the lower animals. So with the heat centres. The chief bone of contention has been to determine just what was injured in a given operation, rather than to doubt the accuracy of the calorimetric method, although this has not escaped criticism. Then, again, different animals were used in different experiments, and discrepant results were obtained in this way, just as in the case of motor localization. At present we have every gradation, from Ott,[*] who locates six cerebral heat centres, two in the cortex and four in the basal ganglia, to Mosso,[†] who, after a full review of all previous work, and numerous experiments of his own, is unable to admit "that there are, in the brain, centres which preside over animal heat."

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* See "Report of the Storrs Station for 1896," p. 91, and "Bulletin 44 of the Office of Experiment Stations of the United States Department of Agriculture," p. 19.

* See description of the arrangements for cooling in "Report of the Storrs Experiment Station for 1896," p. 92, and "Bulletin 44 of the Office of Experiment Stations of the United States Department of Agriculture," p. 22.

The first observer to call attention to cerebral heat centres was Tscheschichin,[‡] who, working with Du Bois Reymond, found that lesions of the medulla in the neighborhood of the pons Varolii were followed by a decided rise in temperature. His work was on rabbits, and he did not use the calorimeter.

This was followed by Lewizky[§] in 1869, and by Bruck and Günter[‖] in 1870, disagreeing with Tscheschichin, and by Schreiber,[¶] in 1874, agreeing, for the most part, with Tscheschichin, and disagreeing with Lewizky and with Bruck and Günter.

This was the status of the question in 1880, when Wood[**] published his elaborate calorimetric researches on fever. Wood found that "section of the medulla at its junction with the pons is followed by increased heat dissipation and heat production, the increased heat dissipation usually keeping pace with the increased production, so that the bodily temperature rises." Wood also found (p. 143) that "destruction of the first cerebral convolution in the dog, posterior to, and in the vicinity of, the sulcus cruciatus is followed at once by a very decided increase of heat production, while after irritation of the same nervous tract there is a decided decrease of heat production." Mild irritation of this region has no influence on blood pressure—its destruction likewise is without vaso-motor effect (p. 153); therefore it is fair to presume that this centre influences body temperature through heat production—not heat dissipation. These earlier researches of Wood were confirmed later by a joint research of Wood, Reichert, and Hare,[††] and by others, who find that there are thermogenic centres which affect the production of heat independently of blood pressure.

Ott,[‡‡] Richet,[§§] and Aronsohn and Sachs,[‖‖] working simultaneously and independently, all claim to have demonstrated the presence, in the brain, of centres which cause a rise of temperature by heat production. Richet and Ott used a calorimeter, Aronsohn and Sachs used the indirect method, determining both O and CO_2.

This work has in the main been supported by the later calorimetric experiments of Ott[¶¶] and of Reichert,[***] and of a number of others who have not employed the calorimeter. These observers, while differing as to the exact location of centres and as to the mode of their action, do agree, for the most part, that such centres exist. Reichert, in the work just quoted, has made an important contribution to our knowledge of heat centres in the spinal cord. He ascribes more importance to them than to those located in the medulla, basal ganglia, or cortex.

The only later writer who takes an iconoclastic attitude with regard to cerebral heat centres, and bases this opposition on experimental data, is Mosso; and he[*] rather leans toward a position advocated by Girard,[†] who says that we cannot speak of a thermogenic centre, but of many such centres scattered in the brain and spinal cord and working together. It is quite probable that, when the confusion now existing is cleared up by later investigations, this view will be found very near to the truth.

Those who wish to study this question more closely are advised to consult the papers of Wood, Ott, Reichert, and Mosso, here quoted; also papers by Hale White[‡] and Riegel.[§] White's paper in Guy's Hospital Reports gives interesting clinical data, which he says support the calorimetrical findings of Wood. The only clinical evidence quoted against cerebral heat centres is a case, reported by Dana,[‖] of a monster in which there was no cerebrum, basal ganglia, or cerebellum, and only part of the pons—yet the temperature was normal. This would support Reichert's theory that the cord centres were the most important.

To sum up briefly our knowledge of heat regulation and body temperature, we may say that the body temperature depends upon the balance between heat production and heat dissipation, each of which is directly controlled by the nervous system. Either of these factors may vary independently of the other, in either direction, so that body temperature may vary, as in fever, as the result of a change in either factor separately or of both acting together. Centres which control heat production are located in the cortex, basal ganglia, medulla, and cord. Some of these produce an increase in metabolism with a consequent increase of heat production, while some appear to diminish metabolism. These are usually regarded as inhibitory to the centres which cause metabolic activity. The spinal cord contains centres which influence heat production, and these are still active after being cut off from the medulla.

There is a marked co-ordination, so to speak, between the centres which control heat production and those which control heat dissipation, the two striking a balance, in warm-blooded animals, which keeps the body temperature practically constant at a certain point. It will be shown, in the following section, that in fever neither of these sets of centres is completely paralyzed, but that the balance is established at a higher point.

The heat-regulating mechanism is more delicate in man than in apes, as shown by the experiments of Lefevre,[¶] which are also of great interest in showing the reaction of the heat regulators of patients in a cold bath.

The Separation of Motor and Trophic Nerves by Calorimetry.—Every muscular contraction is accompanied by the production of heat. It is well known that the muscles are the tissues in which is produced the greatest part of the heat which maintains the body temperature. That this heat may be produced independently of muscular contraction is proved by the fact that the body temperature remains practically constant even when the muscles are at rest, as during repose or sleep. The question arises, Does the same set of nerves control muscular contraction and heat production, or do we have one set (motor) controlling muscular motion and another set (trophic ?) controlling the chemical changes (metabolism) which give rise to heat? The first calorimetric experiments to solve this problem were undertaken by Kemp.[**] Making use of the fact that the drug curare paralyzes only the *endings* of the *motor* nerves, while leaving the nerve fibres and the muscle cells intact,

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[*] Ott, N. Y. Med. Journ., 1889, vol. xlix., p. 247.

[†] Mosso, Arch. Ital. de Biol., 1890, vol. xiii., p. 459.

[‡] Tscheschichin, Arch. f. Anat. u. Physiol., 1866, pp. 169–175.

[§] Lewizky, Arch. f. path. Anat., 1869, vol. xlvii., pp. 356–359.

[‖] Bruck and Günter, Arch. f. d. ges. Physiol., 1870, vol. iii., pp. 578–584.

[¶] Schreiber, Arch. f. d. ges. Physiol., 1874, vol. viii., pp. 576–596.

[**] Wood, "Smithsonian Contributions to Knowledge," No. 357, p. 74.

[††] Wood, Reichert, and Hare, Ther. Gaz., 1886, p. 678.

[‡‡] Journ. of Nerv. and Ment. Dis., 1884, vol. ix., p. 141.

[§§] Richet, Arch. de Physiol., 1885, vol. vi., p. 496.

[‖‖] Arch. f. d. ges. Physiol., 1885, vol. xxxvii., p. 232.

[¶¶] Ott, Journ. of Nerv. and Ment. Dis., 1887–88; Ther. Gaz., 1887, p. 399; N. Y. Med. Journ., 1889, vol. xlix., p. 247.

[***] Reichert, Univ. Med. Mag., 1893, vol. v., p. 406, and 1894, vol. vi., p. 303.

[*] Mosso, op. cit., p. 463.

[†] Girard, Arch. de Physiol., 1888, pp. 326–328.

[‡] Hale White, Journ. of Physiol., 1890–91; Guy's Hospital Reports, 1883–84, vol. xxvii., p. 48.

[§] Riegel, Arch. f. d. ges. Physiol., 1872, vol. v., p. 629.

[‖] N. Y. Med. Journ., 1889, vol. xlix., p. 248.

[¶] Lefevre, Compt. rend. Soc. de Biol., 1894–95.

[**] Kemp, Therap. Gaz., 1889, pp. 86 and 155.

Kemp studied the effect of different-sized doses of curare on dogs, and found that small doses, just sufficient to paralyze the motion of muscles, still allowed the heat-regulating mechanism to function, and the body temperature to be kept up to the normal or even to rise. Larger doses, he found, caused a fall of body temperature and a diminution of heat production as recorded by the calorimeter. His conclusion was that since the nervous system could still control heat production after paralysis of the motor nerve, either the motor-nerve endings paralyzed by curare retained their grip on metabolism after losing it on motion, or, what was more probable, there were two kinds of nerves, the motor and the trophic; the former being paralyzed by a small dose of curare, while the latter required a larger dose to throw them out of function. Two years later Reichert,* as part of an extended research on the rise of temperature produced by cocaine and caffeine, made a number of experiments covering the same ground as Kemp. The two sets of experiments were not under exactly the same conditions, and the results were not absolutely in harmony. The main point of difference lay in the effect of *large* doses of curare. Reichert found that these sometimes produced a fall in heat production, thus agreeing with Kemp; but in other instances he found the heat production could be kept up to the normal or even increased. The observations of both, however, are in thorough accord on the main point involved, viz.: that the heat-regulating mechanism can work through nerves which still function after the motor-nerve endings are completely paralyzed. Reichert also added the interesting observation that cocaine fails to produce its characteristic effects in animals even lightly curarized, while caffeine can still produce an increase in heat production and temperature, though its effects are somewhat modified (p. 250).

Mosso,† in working with curarized dogs, found that a dose of strychnine caused a rise of temperature. He did not use a calorimeter in these experiments. Reichert‡ repeated these experiments and found that strychnine may produce an increase in heat production even when the animal is paralyzed by curare, which is an additional evidence for the theory that nerves, other than the motor, control metabolism in muscles. Reichert finds, however, that the rise of temperature is due more to lessened heat dissipation than to heat production.

Relation of Heat Production and Heat Dissipation to Daily Variations in Temperature.—Every clinician is familiar with the daily fluctuations in body temperature, both in health and in fever. A number of observations have been made on animals and on man to see whether there is a diurnal variation in heat production. Most of these have been by the method of indirect calorimetry, and all unite in showing the profound influence of *digestion* on the heat produced. Fredericq, for example, found the maximum absorption of oxygen to be at 10 A.M. and at 2 to 3 P.M. Vierordt, Langlois, and Ott all agree that the period of maximum heat production is about this time. Fredericq noticed that in a starving man these maxima did not occur, and Langlois found that heat production may rise thirty-five to forty per cent. after a meal. Though we may feel warmer after a meal, it is well known that there is no actual rise of temperature, as shown by the thermometer, whereas the evening rise and morning fall occur, in a well-fed man, whether a meal be missed or not.

Carter,§ in Ott's laboratory, undertook an investigation of the relation of heat production and heat dissipation to this interesting phenomenon. His experiments were made on dogs, cats, and rabbits, both normal and with fever. He first established the fact that these animals have practically the same daily fluctuations of temperature as man, the maximum temperature occurring from 7 to 11 A.M., and the minimum from 7 to 11 P.M. As the result of his calorimetric observations, he found that "the maximum and minimum of heat production and heat dissipation do not occur synchronously with the maximum and minimum of animal temperature. The two are entirely independent of each other"; also, "the heat production and temperature are entirely independent of each other." This was true in fevered animals as well as in healthy ones. There is no paradox in these results, for we must recall, as shown in § 3, that the temperature depends upon two factors, heat production and heat dissipation, and that either or both of these may vary, at the same time, in either direction. What Carter's researches show is the interesting fact that there is something in the body of mammals which causes the balance between heat production and heat dissipation to be established on a different level at different times of the day, and that this something does not reside in the centres which control heat production, nor does it reside in those which control heat dissipation.

Lichatschew * found a closer relation between heat production and diurnal variations of temperature than was found by Carter.

Relation of the Size of an Animal to the Amount of Heat Produced.—As this is a subject of interest less from a medical than from a biological standpoint, and as its discussion would require considerable space, it will not be entered into here.

Most investigators give as a general law, that, *ceteris paribus*, the heat produced by an animal is directly proportional to the cube root of the square of the weight, while Reichert thinks that "if any distinct relation exists between body weight and the quantity of heat produced it is in direct proportion."

Those interested in studying this question more closely are referred to papers by Rosenthal,† Reichert,‡ and Richet,§ the latter of whom takes up a discussion of the effect of artificial conditions of the skin, such as shaving an animal, coating it with oil, clothing, etc.

§ 6. CALORIMETRY IN PATHOLOGY.—The chief use of calorimetry in pathology has been in connection with the study of fever. Some interesting results have also been obtained from investigating the effects on the system, of the products of the growth of specific micro-organisms; these latter will be taken up in § 7, on "calorimetry in experimental pharmacology," so that the present section will deal only with calorimetry in fever.

Lavoisier's theory, that animal heat resulted from combustions in the body, gained general acceptance about the beginning of the nineteenth century, and from that time until 1863 there was a strong feeling among pathologists that pyrexia was the direct result of abnormally great oxidation in the body. The conflicting theory put forward in 1863 was that of Traube,‖ who attributed the pyrexia to *retention* of body heat, due to a constriction of blood-vessels in the skin, the result of which was to keep the heat of the blood from being lost by radiation at the surface. Traube's chief opponent at this time was Liebermeister, who attributed the rise in temperature to an increased heat production, denying that an increased heat retention ever took place.

Numerous experiments have been made by indirect calorimetry, to determine whether there was an increased oxidation of food or of the tissues in fever, and the oxygen used, the CO_2 given off, and the nitrogenous waste excreted have all been taken into account. The results of these researches have not been in harmony, but from some of the most trustworthy we would gather that while the fever is on the rise, there is an increase in the oxygen used and the CO_2 given off, while the opposite is true for the decline of pyrexia. While the fever remains constant more oxygen is used and more CO_2 is given off than in health (nutritive conditions being the same), but there is not as high a percentage increase as when the temperature is rising. Most observers found that the respiratory quotient (vol. $CO_2 \div$ vol. O) is the same in fever as in health, but Regnard,* one of the most competent, says that it is diminished, which would mean that the character, as well as the amount, of metabolism was affected in fever.

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* Reichert, Therap. Gaz., 1891, pp. 151, 242.
† Mosso, Virch. Arch., vol. cvi., p. 80.
‡ Reichert, Therap. Gaz., 1892, p. 386.
§ Carter, Journ. of Nerv. and Ment. Dis., 1890, vol. xvii., p. 785.

* See Richet's "Dictionnaire de Physiol.," vol. iii., p. 135.
† Rosenthal, Arch. f. Physiol., 1889, p. 31.
‡ Reichert, Univ. Med. Mag., 1890, vol. ii., p. 225.
§ Richet, article "Chaleur," in Richet's "Dictionnaire de Physiol.," Paris, 1898, vol. iii., pp. 127–138.
Traube, Allgem. med. Centralzeitung, 1863–64.

Such experiments as these give valuable information about the chemical processes in the body during fever, and show that in fever there is increased oxidation, and hence increased heat production, as a rule; but they do not settle the question at issue between Liebermeister and Traube, viz.: "Does heat dissipation enter as an essential factor?" This can be answered only by direct calorimetry, as pointed out by Senator † when he undertook the first thorough series of investigations on the subject.

Leyden had already made this question the subject of calorimetric research, but his method was the unsatisfactory one of partial calorimetry by baths.‡ His results, however, were in harmony with those of Senator and of Wood, in 1880, the latter's experiments being the most complete we have in calorimetry on fever. These observers all find that both heat production and heat dissipation play an important part in fever, thus showing that each of the older theories of Liebermeister and of Traube was partly right, but neither entirely so. This position has been substantiated by practically all later investigations. Our present views concerning the general pathology of fever cannot be better given than by the following quotations from some of the numerous generalizations of Wood: §

(α) "The rise of temperature in fever is not dependent altogether upon increased heat production, as in fever there certainly is sometimes less production of heat in the organism than there is at other times when the bodily temperature remains normal; also excessive heat-production may occur even at the expense of the accumulated materials of the organism without elevation of the body temperature."

(β) "In fever a daily temperature variation occurs which is parallel to that seen in health, and differs from the normal variation only in having a higher mean."

(γ) "In fever vaso-motor paralysis, when produced, is followed by an immediate fall of temperature similar to, but greater than, that which is produced by a like disturbance in health."

(δ) "The decrease of heat production which follows section of the cord is much greater in the fevered than in the normal animal."

(ε) "The so-called inhibitory heat nervous system is not paralyzed in fever, but is less capable than in health of answering promptly and powerfully to suitable stimuli; in other words, it is in a condition of paresis or partial palsy."

(ζ) "The clinical succession and phenomena of a febrile paroxysm, such as that of an intermittent, seem plainly to depend upon the nervous system for their arrangement and relation."

(η) "Irritative fever, if it exists, is produced by an action of the nervous system."

(θ) "Fever occurring in cases of blood poisoning is often, and probably always, the result of a direct or indirect action of the poison upon the nervous system, and hence is a neurosis."

According to Mosso,‖ there are two kinds of fevers: one produced by the nervous system, and one independent of the nervous system, which has its origin in the tissues themselves. He claims that cocaine produces fever through the nervous system; while cultures of staphylococcus pyogenes aureus, injected into the blood, produce fever by direct action on the tissues. He has found that chloral will prevent the rise of cocaine fever, but is without effect on the fever produced by the staphylococcus.

This question of the probable different origin of different fevers is an exceedingly interesting one, and would afford a fruitful field for further research. Certain drugs will influence one kind of fever but not another, and a careful study of this question would throw light not only on the action of drugs, but on the pathology of fever itself.

Before leaving the subject of calorimetry in fever, two clinical papers should be mentioned, since each was written with direct reference to previous calorimetric work, and deal with the relation of the nervous system to fever. After reading them, one can scarcely doubt that "fever of purely nervous origin" exists. The papers are those of Drs. Hale White and Mary Putnam-Jacobi.* White,† after a masterly review and synopsis of fourteen cases of lesions of the central nervous system, with clinical history and post-mortem findings, concludes that the results of Wood's experiments on dogs are corroborated by clinical and pathological observations on man.

§ 7. CALORIMETRY IN EXPERIMENTAL PHARMACOLOGY.—In this section it is not proposed to discuss the physiological action of the drugs and poisons considered, but simply to show which of these substances have been investigated by direct calorimetry, and what direct calorimetry has done for medicine along this line. Unfortunately, many of the findings which will be mentioned are based upon too few experiments, so that the value of this section will be to call attention to work thus far completed, and needing, for the most part, corroboration, rather than to show positively established facts in connection with the drugs or poisons. Only researches employing direct calorimetry are mentioned.

DRUGS.

Antifebrin.—Hare [1] finds that antifebrin reduces normal temperature, and in so doing affects both heat production and heat dissipation.

In fever it reduces pyrexia chiefly by decreasing heat production. It seems to have little effect on pepsin fever (see Pepsin, this section).

Antipyrin.—Wood, Reichert, and Hare [2] find that antipyrin lessens heat production independently of any action on the circulation. They think it influences the chemical changes in the body through the nervous system, especially the heat-inhibitory centre.

Girard [3] found that a lesion (*piqûre*) on the median side of one of the corpora striata produced less effect after giving antipyrin than before.

Martin [4] destroyed Ott's inhibitory heat centre, and found that antipyrin produced an increase of heat dissipation, the same dose not always giving the same quantitative results. Heat production was reduced in four out of six cases. He compared hydroquinone, antipyrin, thallin, and kairin, and all gave the above result. "As a rule, heat production followed heat dissipation, in its ups and downs, although the drugs sometimes reversed matters," especially antipyrin.

Gottlieb [5] attributes the fall of body temperature, after antipyrin, exclusively to increased heat dissipation. He says there is no concomitant diminution in heat production.

Atropine.—According to Ott,[6] atropine causes increased heat production and increased heat dissipation, the effect on heat production being the greater—consequently temperature rises.

Lewis [7] finds that small doses of atropine produced increased heat production and diminished heat dissipation, while with large doses the temperature fell with increased heat dissipation in spite of increased heat production.

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* Regnard, "Recherches expérimentales sur les variations pathologiques des combustions respiratoires," Paris, 1878.

† Senator, "Untersuchungen über den fieberhaften Process," etc., Berlin, 1873, p. 2.

‡ See § 4, "Calorimetry by Baths."

§ Wood, "Fever: A Study in Morbid and Normal Physiology," Philadelphia, 1880; also "Smithsonian Contributions to Knowledge," No. 357, pp. 254 et seq.

‖ Mosso, Arch. Ital. de Biol., 1890, vol. xiii., p. 483.

* Jacobi, Journ. of Nerv. and Ment. Dis., 1890, vol. xvii., p. 373.

† White, Guy's Hospital Reports, 1883-84, vol. xxvii., p. 48.

Caffeine.—Reichert[8] finds that, under caffeine, heat production is always increased, while heat dissipation is not affected in any constant way. Curare modifies but does not check the action of caffeine.

Carbolic Acid.—Hare[1] (p. 525) gives a summary of his work with carbolic acid as follows: "Carbolic acid possesses considerable power in lowering normal bodily temperature. It possesses more influence over pyretic temperature than does salicylic acid, generally preventing a rise or causing a fall of temperature, but sometimes failing to do so. Its mode of decreasing normal bodily temperature is as yet not fully understood, although it would seem probable that it acts on both heat functions. When reducing bodily temperature in fever, it acts chiefly by decreasing heat production, although it affects both functions."

Chloral.—Bevan Lewis[7] says: "Hammarsten's statement that the rapid fall of temperature is dependent upon diminished heat production . . . is, I consider, fallacious; in fact, all my observations tend to confirm the statement previously made, viz., that the heat production is greatly increased, and that the fall of temperature is really dependent upon the increased dispersion of heat from the body, ensuing from exposure during very general vascular dilatation."

Cocaine.—As the result of a very complete research Reichert[9] finds that cocaine increases both heat production and heat dissipation. Its action on heat production is much the greater, so that temperature rises. Curare seriously interferes with the action of cocaine.

Curare.—See experiments of Kemp and of Reichert, § 5, Calorimetry in Physiology.

Ergotine.—Ergotine, according to Bevan Lewis,[7] produces a fall in heat production, with fall in temperature, followed by a rise in both.

Hydroquinone.—See Martin's[4] "Researches on Antipyrin," above.

Hyoscyamine.—Bevan Lewis[7] found that hyoscyamine always produced great commotion in heat production and heat dissipation, but no constant effect could be ascribed to it.

Kairin.—See Martin's "Researches on Antipyrin," above.

Neurin.—Ott[10] found that neurin produced fever by action on the nervous system independently of the circulation.

Pepsin.—Many forms of commercial pepsin, when rubbed up with water or salt solution, and injected into the blood, produce a decided fever apart from their action on the circulation. This fever is the result of an effect on both heat production and heat dissipation, the former being the more affected. The active substance in these cases is not pepsin, but proteoses and peptones, which are found along with the pepsin (see Ott,[10] and Wood, Reichert, and Hare[2]).

Peptone.—See Pepsin, above.

Proteoses.—See Pepsin, above.

Phenol.—See Carbolic Acid, above.

Picrotoxin was found by Bevan Lewis[7] to increase, enormously, heat production. The effect lasted longer than that of strychnine. Heat production then fell to a minimum just before convulsions set in.

Quinine.—Wood, Reichert, and Hare[2] investigated the action of quinine with the calorimeter, and found both heat production and heat dissipation to be affected. We quote them as follows: "We do not think that our results are sufficient to positively determine whether heat production or heat dissipation is the function which is primarily influenced." They think that quinine's chief value is due to its "stimulating or restoring the normal tone of the centres which are connected with thermogenesis, so as to enable them to resist the morbific fever-producing influences.

Another author* finds that doses of 0.1 to 0.2 of quinine lower the heat production in rabbits. In normal animals the diminution is from eight to eighteen per cent., in animals with fever from *piqûre* the diminution may be as high as forty per cent.

Salicylic Acid.—Hare[1] finds that salicylic acid can reduce normal temperature slightly; it has little power over the temperature in fever. In reducing normal temperature it probably acts on both heat production and heat dissipation; its action on fever is uncertain and irregular.

Solanine.—This alkaloid was studied by Bevan Lewis,[7] who found that its vaso-motor effect produced diminished heat, dissipation of heat, with consequent rise of temperature. This rise took place in the face of an enormously reduced heat production.

Strychnine.—Bevan Lewis[7] found that strychnine increased heat production—the best effects were from small doses. Chloral counteracts the effect of strychnine.

Thallin.—Martin[4] found that thallin regularly increased heat dissipation, but had no constant effect on heat production (see also Antipyrin, above).

BACTERIAL POISONS

Tuberculin.—D'Arsonval and Charrin* found that tuberculin raised the rectal temperature and at the same time diminished heat production.

Pyocyaneus (bacillus).—Certain poisons produced by this bacillus had the same effect as tuberculin mentioned above.*

Pyogenes aureus (staphylococcus).—See account of Mosso's work in § 6, Calorimetry in Pathology.

George T. Kemp.

[1] Hare, Ther. Gaz., 1887, p. 389.

[2] Wood, Reichert, and Hare, Ther. Gaz., 1886, p. 811.

[3] Girard, Rev. méd. de la Suisse Romande, 1887.

[4] Martin, Ther. Gaz., 1887, p. 289.

[5] Gottlieb, Arch. f. exp. Path. u. Pharm., 1891, vol. xxviii., p. 184.

[6] Ott, Ther. Gaz., 1887, p. 514.

[7] Bevan Lewis, West Riding Asylum Reports, 1876, vol. vi., pp. 43-64.

[8] Reichert, Ther. Gaz., 1891, p. 249.

[9] Reichert, Univ. Med. Mag., 1889, vol. i., p. 448; and Ther. Gaz., 1891, p. 249.

[10] Ott, Journ. of Nerv. and Ment. Dis., 1884.

CALYCANTHUS.—(Properly *Butneria.*)—A genus of three species of shrubs in the family *Calycanthaceæ* growing in the United States. The bark and leaves of *B. fertilis* (Walt.) Kearney, commonly known as the sweet-scented shrub or strawberry shrub, are used in domestic practice as an antiperiodic. The plant is chiefly of interest because of the poisonous nature of the seeds, sheep being killed by eating the fruit. An alkaloid, calycanthine, has been extracted by Dr. R. G. Eccles from these seeds. *H. H. Rusby.*

CAMDEN, S. C.—Situated in the pinewood, sandhill region of the State, about 30 miles from Columbia and twenty hours from New York. It is a town of 3,500 inhabitants, between 150 and 200 feet above sea level, and is a winter health resort particularly suitable for cases of pulmonary tuberculosis. The soil is very dry and porous, so that after a heavy shower the roads are not wet, the water quickly soaking into the sandy soil. The water supply and drainage are said to be good and the accommodations excellent, there being two hotels and a number of boarding-houses. The climatic data are as follows:

Mean temperature (Fahrenheit): spring, 61.90°; summer, 79.32°; autumn, 62.26°; winter, 45.16°. Average annual rainfall for twenty years, 42.22 inches. The coldest noon temperature in February, 1890, was 50°; in March, 40°; in April, 50°. The warmest noon temperature was: in February, 83°; in March, 81°; in April, 86° (Solly). The prevailing winds are south and southwest. In February and March there are some high winds, but generally the air is remarkably soft, dry, and balmy.

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* These observations were found among the writer's notes without a reference to the original paper.

* D'Arsonval, Arch. de Physiol., 1894, p. 362.

"Frosts occur at night only, and snow is exceptional." The exact number of sunny days is not known, but is said to be large. The relative humidity, though not known for this place, is probably not very different from that at Aiken, which is 59 per cent. for December, January, and February.

The especial advantages claimed for this region as a health resort are "its dry, balmy, bracing air, with conditions favorable for constant out-of-door life"; its dry, sandy soil; the pines, and its easy accessibility.

Camden would appear to be a good resort for the open-air treatment of pulmonary tuberculosis, for cases not suitable for the colder regions or altitudes; also for convalescents from influenza, pneumonia, or pleurisy, and for those who merely desire to escape the dampness and cold of the Northern winter. *Edward O. Otis.*

CAMP DISEASES.—There are no diseases peculiar to the soldier, but those by which he is chiefly affected are such as not infrequently occur among males of the military age in civil life. The conditions of military service, however, are often such that various factors predisposing to deviation from the standards of health are greatly increased in potency; while the directly exciting causes often operate much more frequently, act over longer periods, and, in the case of infectious diseases, not rarely assume greater virulence. Since all these diseases have their counterparts in civil life, any extended discussion of their etiology, pathology and symptomatology is unnecessary in this connection; and the treatment of such diseases also varies in no wise from that employed by the more advanced members of the medical profession throughout the civilized world. There remains, then, for discussion the relative importance of various diseases as affecting the health of troops; the predisposing causes, in so far as they are influenced by military service and conditions; the special methods of infection and the dissemination of infectious material; and, finally, the means of preventing such diseases, as based chiefly upon the special military conditions by which the occurrence of the disease is favored or brought about.

Excluding traumatism, the causes which chiefly impair the health and efficiency of troops, in garrison or during campaign, may be grouped according to their relative importance, as follows:

1. Diseases of an infectious character, the spread of which, in the military service, is favored by the aggregation of young and susceptible individuals, ignorant or careless in regard to matters of personal hygiene, living under conditions implying intimate personal relationship, constant contact and, frequently, overcrowding. In many instances the necessities of military service require an existence in unhealthful localities, favorable to the development of pathogenic micro-organisms and under circumstances in which their opportunities for dissemination and entrance into the system are much greater than in civil life. In addition, the occurrence of these diseases is also often markedly favored by depression of the powers of vital resistance, depending upon great fatigue, exposure to inclemencies of weather, insufficient or improper food, impure water and vitiated air. These diseases assume far greater importance during active service in the field than in garrison, being the chief cause of inefficiency among troops during campaign.

2. Diseases due to immoral or intemperate habits; as favored by an enforced celibacy, the absence of wholesome home restraint and the monotony often attaching to garrison life. These diseases are factors of the first importance in time of peace in raising the sick rates of an army, but during active warfare or field service they sink into comparative insignificance.

3. Diseases the causative agents in which are unknown, but which appear to be largely excited by exposure to cold, wet and dampness, whether they be found in camp or garrison. These affections have but little tendency toward a fatal result, and their importance from the military standpoint lies in the considerable proportion of temporary unfitness for service which they produce. The number of soldiers who are temporarily incapacitated for all or part of their duty, from these causes, is always large.

4. Affections due to extremes of temperature. Such are obviously related to climate and season, and are largely influenced by nature of service; being naturally much more frequent among troops on campaign than among those in garrison.

5. Disease due to an improper dietary; this being largely dependent upon facility of supply and transportation, and hence being obviously more frequent among troops on active campaign or serving at remote, isolated, and newly established stations.

6. Disease directly induced by military service. This may be of a functional or organic nature, and is largely dependent upon the muscular labor involved in the execution of military movements, the method of disposing the equipment upon the person, and the mental condition often resulting from field service and conflict. Pathological conditions of this character are rarely observed in garrison, but are by no means infrequent during campaign.

In the detailed consideration of the diseases of the soldier, it is obvious that only such as exert a certain positive influence upon military efficiency require discussion. To consider a number of rare affections, from the liability to which the soldier is no more free than the young man of the military class in civil life, and upon the occurrence of which military service appears to exert neither positive nor negative influence, is clearly both unnecessary and undesirable.

I. Infectious Diseases.

Asiatic Cholera.—*Occurrence.*—The military history of cholera begins with the year 1757, when the British troops in India suffered greatly from its attacks. It is said that one division of 5,000 men had 500 deaths from cholera in a single day. In 1817, according to Rosse, in a force under Hastings the onset of a cholera epidemic was so sudden that sentries fell as if struck by lightning, and it required three or four men to stand a tour of guard duty of two hours. In five days there were 5,000 deaths, and the command was almost destroyed. In 1821, cholera made such ravages in the armies of Turkey and Persia that it forced military operations in Mesopotamia to be brought to an end. In the years 1830–1831 cholera extended all over Europe and was shortly afterward brought to this country. Troops were attacked at a number of stations. At Fort Dearborn, on the present site of Chicago, it is stated by Rosse that 200 men out of a garrison of 1,000 were admitted to hospital with cholera in the course of seven days. During the Crimean War there were 7,375 cases of cholera in the British army, with 4,513 deaths. In the French army, at the same time, there were 12,258 cases with 6,013 deaths. Among the French troops composing the ill-fated Dobrutscha expedition, it is said that at one time no less than 10,000 men lay dead or struck down by cholera. Out of one battalion, besides those already dead, 500 sufferers were carried in the wagons. Coustan states that in one division of 10,590 men there were 2,036 deaths. In 1866, during the war between Austria and Prussia, more deaths occurred from cholera, in the armies of the latter country, than resulted from battle. At the close of the Civil War our troops suffered severely from cholera; there being, in 1866, 2,813 cases and 1,269 deaths. In 1867 there were 504 cases and 230 deaths, and in 1868 there were 7 cases and 3 deaths. Cholera almost destroyed a body of recruits marching from Leavenworth to Fort Hays, in Kansas, and was also epidemic at Fort Riley and other stations. It was carried by recruits from New York to California, Louisiana, Texas and Georgia. In 1866 it also broke out in Brazil and the Argentine, and was carried by the armies into Paraguay. In the outbreak of 1873, in this country, our army was little affected, there occurring but 12 cases with 8 deaths; and since that year there have been no further deaths from this cause in our service. The

French army has suffered with the civil population during the various outbreaks of cholera in France and Algeria. Rosse states that in Paris, for the period 1832–49, and again in 1853, the mortality from this cause was 14.76 per thousand among the civil population, and 42.59 per thousand among the garrison troops. In many later instances, however, especially in the outbreaks of 1884 and 1893, the greater care as to sanitary conditions in the military service preserved the soldiers, while deaths occurred in the surrounding civil population. In the British army, during the decade 1888–97, cholera occurred among troops in India, Egypt, China, and Ceylon. In India, for this decade, the admission rate per thousand was 1.8; the death rate, 1.29. Cholera figures almost annually in the returns for the Russian army, certain military garrisons of which are located in regions at which the disease endemically prevails. Recent figures for cholera in the Russian army are as follows:

	Admissions per 1,000 strength.	Deaths per 1,000 strength.
1890	0.06	0.02
1891	—	—
1892	4.3	1.83
1893	1.61	46
1894	1.00	.35
1895	.40	.10
1896	.01	002

Dissemination and Infection.—The specific causative agency in cholera is given off chiefly by the bowels, and to a less degree in the vomitus. The length of time during which the stools of a cholera patient are infectious is unknown, but it probably is a considerable period. As with typhoid fever, apparently healthy persons appear at times, during an epidemic, to act as hosts for the bacilli and play a part in the propagation of the disease. While the disease at times follows contact with the sick, it may fairly be regarded as only slightly contagious and not likely to be contracted except by indirect infection. The latter undoubtedly occurs by way of the alimentary tract. There is no proof that air ever serves as the vehicle for the transmission of cholera bacilli; though in this disease, as in typhoid fever, its dissemination by this means should be regarded as possible. Water has long been recognized as the chief agent in the spread of cholera; and abundant circumstantial evidence to this effect is fortified by a number of instances in which the specific etiological factor has been discovered in suspected water by bacteriological investigation. Many instances have been reported in which the infection of a water supply was followed by outbreaks in communities further down the stream. In the epidemic of Hamburg, in 1892, the part played by an infected water supply was most marked; the proportionate number of cases being eight times greater in that part of the city in which unfiltered water was supplied, than in the part in which the drinking-water was partially purified by sand filtration. Recently, among the British troops at Umballa, in India, an epidemic of cholera promptly ceased as soon as a supply of sterilized water was provided for drinking purposes. Cholera bacilli flourish best in sluggish streams, and especially in water containing a considerable proportion of organic matter. Under certain circumstances, not as yet fully understood, the bacillus is capable of rapid multiplication in water, but many saprophytic micro-organisms are hostile to its development and appear to destroy its vitality in the course of a few hours or days. Any specific contamination, however small, is capable at times of imparting to enormous quantities of water the power of originating the disease. Earth undoubtedly may serve as a medium for the development of the bacillus outside the human body. At Lucknow, 90 soldiers out of 600 died of cholera apparently as a result of placing fresh sand, taken from the bank of a river used as a general bathing place, in a filter from which water was drawn for the use of the command. Food contaminated by cholera discharges also serves as an agent for the spread of the disease. This is rarely directly infected, but is contaminated by manipulation with unclean hands, by contact with infected objects, by dust containing the specific germs, or by the agency of flies which have recently fed on cholera discharges. In India, medical officers now regard the latter as one of the more common agencies by which the spread of cholera is accomplished. In the Burdwan prison, where other means of infection were scarcely possible, it is said by Buchanan that an epidemic was directly traceable to flies which were carried over the prison wall by a high wind blowing from the direction of some native houses, in which the disease had occurred. During the outbreak in the Gaya jail, Macrae found that milk to which flies in the jail were given access invariably became infected with comma bacilli; and he concluded that "flies should be looked on in the light of poisonous agencies of the worst kind during cholera epidemics." The cholera bacilli may be carried in fomites, particularly in baggage, rags, or clothing, soiled with the fæcal discharges of the sick. Under such conditions they retain their vitality for considerable periods, though they are readily destroyed by sunlight and desiccation. As in typhoid fever, the disease germs may be carried into camp or barracks on the shoes of individuals who have visited an infected latrine or locality. Marching troops, when infected, have done much to spread the disease to districts in which it was previously unknown.

The period of incubation of cholera is usually about three days, but this, under rare circumstances, may extend to as much as ten days.

Predisposing Causes.—Cholera prevails endemically in India, from which it extends from time to time. It appears to be a settled fact that where the disease prevails in an endemic form it does not occur in great epidemics. A severe outbreak appears to confer upon the locality attacked a more or less complete immunity; the durability of which, so far as India is concerned, appears to last for a number of years. A high temperature is a predisposing cause of great importance; but while many epidemics have ceased with the advent of cold weather, this is by no means always the case. In the tropics, cholera prevails to the greatest extent at the close of the dry season. A moderate rainfall tends to cause the further development of the disease, but where the rains are heavy and continued, a marked diminution in the occurrence of cholera is observed. There is a general consensus of opinion that the incidence and severity of the disease are greater among negroes than among whites. In the United States, during the epidemic at the end of 1866, the mortality among the white troops was 77 per thousand, while among the colored troops it was 135 per thousand. When the disease prevails endemically, the native population appears to enjoy a considerable but not absolute immunity to it. In the Hedjaz and in the sparsely populated parts of Arabia, it is said by Fauvel that the disease manifests only a feeble tendency to propagate itself among the native population. This immunity, however, is not shared by strangers visiting a locality endemically affected. As a race, the Chinese appear to be notably free from the ravages of cholera, probably chiefly from their general use of sterilized water in tea. In any outbreak of this disease, numbers escape attack through their hereditary or gradually acquired powers of resistance. For epidemics of cholera a stratum of moist soil pervious to air, in which organic material is decomposing, affords the most favorable condition. General sanitary defects, by which the specific fouling of soil and water is possible, are essential to the development of an epidemic.

It has long been observed that the poorer quarters of a community suffer by far the most during a cholera visitation. Epidemics also prevail more severely in low-lying regions than on high ground. Insufficient, poor, or coarse food, improper clothing, and inadequate shelter favor the occurrence of cholera; and physical and mental depression are both markedly predisposing causes. Overcrowding is also a factor of importance. Those affected with catarrh of the intestinal tract and diseases of the digestive apparatus are particularly susceptible to cholera infection.

Prophylaxis.—In view of the fact that in practically every instance of an outbreak of cholera, in regions or communities in which it is not endemic, its origin has been traced to importation from abroad, it is manifest that where practicable a system of quarantine should be established as soon as the danger of an introduction of the infection is recognized. No person from the infected locality should be admitted within the military lines without undergoing examination, and after detention under observation for a period of ten days. All clothing and similar articles should be disinfected before being passed, supplies intended for food unless carried through the affected district in unbroken packages, should not be admitted. Special cholera hospitals, in readiness for an outbreak, should be established and provided with a special staff of attendants. They should not be located at too great a distance from the troops, from the rapid nature of the disease. Such hospitals should possess separate facilities for the isolation and treatment of suspects as well as well-defined cases of cholera.

When the disease prevails, all soldiers suffering from diarrhœa, no matter how insignificant it may appear, should be regarded as suspicious and should be subjected to the same vigilant supervision as applies to recognized cholera patients, for many of these cases, though mild, are nevertheless true cholera and capable of disseminating this disease. Because of their apparently innocent nature these cases often escape the attention their importance demands; and unless it be borne in mind that they are a grave menace to all with whom they are associated, and are treated as such, they can be regarded only as most dangerous sources for the dissemination of disease—far more so than the severe cases which attract attention from the outset. Frequent inspection of latrines should be made and the character of the discharges noted in this connection. Convalescents from cholera should be kept isolated, and the evacuations from the bowels should be disinfected, until bacteriological examination demonstrates that the specific micro-organism causing the disease has disappeared from the discharges. Such individuals should be returned to their respective organizations only after a disinfecting bath and after donning a complete outfit of clothing sterilized throughout. The antecedents of each case of cholera should be investigated, and all those who have been in immediate association with the patient should be placed under observation.

As cholera germs can live and multiply for a time outside the body in the presence of decomposing organic material, more particularly that of animal matter, there should be a thorough removal of every sort of filth and refuse from the camp or garrison. Thorough cleansing, airing, painting, or lime-washing should be carried out wherever indicated. It should not be forgotten that, although desirable at all times, measures of cleanliness taken beforehand are of far more value for protection against cholera than policing which is delayed until after the disease has actually made its appearance. All water used for drinking purposes should be sterilized, preferably by heat. Under all circumstances, in time of cholera, an immediate and searching examination of the sources and conduits of the water supply should be made, when it is in any way open to the suspicion of impurity. When pollution is found to have occurred, every care should be taken to prevent such pollution from continuing and the water from being utilized. When the water supply is believed to be at fault, bathing of the person, except with boiled water, should be discouraged. For marching troops, great care should be taken to prevent the use of water from the supplies of infected towns. Tea has been much used by British troops during outbreaks of cholera in India, as being more palatable than ordinary boiled water. Acidulated drinks containing sulphuric acid, acetic or citric acid, may sometimes be given with advantage. Red wine is also recognized as destructive to the cholera bacillus, and a ration of this, taken diluted in water, might well be issued during an epidemic. The food supplied should be abundant, simply prepared and readily digestible. Particular care should be taken to insure the condemnation and rejection of any food of unsound character capable of exciting a diarrhœa. With the exception of acid fruits protected by an outer rind, as oranges and lemons, no article of food should be eaten that has not been subjected to a boiling temperature in its preparation. Under no circumstances should the use of uncooked vegetables in salads be permitted. All food and drink should be carefully protected against access by flies, since some of these may have previously come in contact with cholera discharges. Prior to use, all vessels used for the cooking, serving, or storing of food should be sterilized by immersion in boiling water. The purchase of food or drink by the men at points outside of military control should be prohibited. The hands of all should be washed before eating. Troops should be well clothed, sufficiently to protect against cold, chilling and moisture. It is during outbreaks of intestinal disorders that the use of the abdominal band is of most advantage. The clothing should be frequently changed, washed, and sunned.

There should be no unnecessary exposure to sun, rain, or night air; and no drills or fatigue other than to furnish occupation and needful exercise. The size of the guard and the length of the tours of duty should be reduced as much as military conditions permit. In addition to fatigue, nothing is more conducive to the spread of the disease than fear and unusual excitement, and a quiescent state of mind should be enjoined upon all. In general, the troops should be regarded as engaged in campaign against an insidious and implacable enemy, and the attention of every officer should be devoted to superintending the conduct of his subordinates with special reference to this view.

In time of impending epidemic, troops should be scattered. A change of soil and locality often appears to be of advantage, and camps should be moved as often as a new case appears. Troops that have fallen back before the advance of the disease have often escaped seizure, or have avoided further sickness if withdrawn subsequently to their attack.

A temporary abandonment of an infected locality is strongly to be recommended. When the disease has actually occurred, efforts at disinfection should be primarily directed toward the vomitus and fæcal matter. These should, as far as possible, be burned. If the cases occur on board transports, the excreta should be received in vessels and not discharged overboard, particularly if in harbor. The disinfection includes that of the barracks, tent, or place occupied by the sick, and the articles of clothing and bedding with which they may have come in contact; and upon its promptness and thoroughness, together with isolation of all those attacked by cholera and their attendants, depends the arrest of the epidemic. If due care in regard to cleanliness and disinfection be observed, there is comparatively small risk that the disease will spread to those who nurse or otherwise attend upon the sick.

As a method of prophylaxis against cholera, inoculations with a specially prepared virus have been systematized and successfully practised in India by Haffkine.

A large number of individuals—upward of 100,000—have been inoculated by him against cholera; among them a number of white and native soldiers in the British service. While the results have varied greatly, they are on the whole distinctly favorable. Among 1,526 non-inoculated soldiers at Dinapore and Cawnpore, there were 25 cases, while among the 268 inoculated there were no cases. In Calcutta, from the tenth to the four hundred and fifty-ninth day after inoculation, cholera visited 26 houses. Among the 263 uninoculated inmates there were 14.45 per cent. attacked, while among the 137 inoculated the proportion attacked was only .75 per cent. The East Lancashire regiment also received weak protective inoculations. Some months later it was exposed to cholera, and the death rate showed the prophylactic value of the inoculation. According to Simpson, 654 individuals who were not protected against cholera had, during the next two years, a mortality of 10.86 per cent.; while of 402 members of the same households, inoculated by him, the mortality from cholera, during the same period, was but 2.99 per cent.

Bubonic Plague.—*Occurrence.*—With the recent occurrence of plague in the Philippine and Hawaiian Islands, this disease at once assumes a practical importance to the army medical officer. Plague has not in recent years figured to any extent among the diseases affecting troops; but numerous epidemics have been reported in the past. The destruction of the Assyrian army, recorded in 2 Kings, was probably due to plague; and the disease described by Thucydides as affecting the 200,000 men immured in Athens, during the Peloponnesian War, presented the symptoms of the catarrhal form of this disease. Plague ravaged the armies of the Crusaders, and it is said that in the first Crusade no less than 50,000 men died of this disease before Antioch. The soldiers of Cromwell died of plague as well as typhus; and it prevailed among both French and English during the first occupation of Egypt. In 1816 plague was introduced into Arabia by the Egyptian army, and it has since prevailed there endemically. An epidemic of this disease is said to have occurred as late as 1828, in the Russian expedition against Turkey. Plague prevails endemically in China, Western Asia, Northern Africa, and perhaps India; from which points it has from time to time extended. It has recently visited Uruguay, Brazil, Mexico, and, in this country, California. It has also been lately transported to New Zealand, Madagascar, South Africa, New Guinea, and a number of islands in the Pacific, among which are possessions of our own. Recently it has occurred among the employees of the Quartermaster's Department at Manila.

Predisposing Causes. — The mortality from bubonic plague varies with different epidemics. Race exerts a marked influence both on the occurrence of the disease and the mortality. Of late years, whites in the Orient have rarely contracted the disease; and, when so affected, the mortality is low. In the epidemic at Hong-Kong, in 1894, Lawson states that the percentage mortality of those attacked was as follows: Europeans, 18.2; Japanese, 60; Malays, 100; Chinese, 93.4. The disease is pre-eminently favored by want, privation and lack of proper sanitation. Meteorological conditions appear to have little influence on the occurrence of plague.

Propagation and Dissemination.—Plague has arisen so uniformly in unclean places that filth is regarded as an essential factor in its propagation and spread. Almost without exception, plague centres have been characterized by a soil polluted by decomposing animal material and by the overcrowding of a dirty and insufficiently nourished population. Plague bacilli have been isolated from the dust of infected houses, and the affection is generally regarded rather as a ground than a water disease. When the microbe is removed from a soil saturated with organic filth, it appears to lose much of its virulence. In the epidemic in Hong-Kong, in 1894, Lawson was impressed with the part which dust and dirt played in the transmission of the disease. The bacillus has been shown to be capable of surviving for two weeks in water, and hence the supply used for drinking and purposes of cleanliness should be pure. While the disease appears undoubtedly to be transmitted by air, this is possible only within a small radius, and there is considerable evidence to show that it may be transmitted by means of food. The disease may be spread by means of clothing and other articles which have been used by plague patients; but is most often disseminated by human intercourse. Aoyama believes that the plague bacillus gains entrance to the body largely through skin wounds, and much less frequently than has been supposed by way of the respiratory and alimentary tracts. The fact that there may be no local manifestations at the point of entrance is important.

A large number of animals, particularly rats, mice, and small rodents, are susceptible to the disease. Rats die in great numbers in pest-smitten districts, sometimes before the epidemic occurs in human beings. There can be little doubt that these animals play the most important part in distributing the disease over wide areas, when it has once broken out. This has been abundantly proved in the case of Bombay, where observation has shown that the emigration of plague-infected rats to districts comparatively free from the disease has been attended by an extensive outbreak in those places. In addition to the pus of suppurating buboes and the blood, the bacilli have also been found in the sputum, urine, and fæces of both men and animals. Further, it has been shown that the flea is frequently an agent by which inoculation is made from affected to sound animals. Pest bacilli have been found in the stomach contents of these insects, and fleas taken from plague-afflicted rats have been made the means of communicating the disease to healthy animals. Nuttall, Yersin, and Ogata have found pest bacilli in large numbers in the bodies of flies in an infected locality. Even after forty-eight hours' retention in a clean receptacle without infected food, infected flies were full of virulent plague bacilli. The experiments of Nuttall and Ogata also tend to show that ants and mosquitoes may be the carriers of this disease, the latter producing infection by direct inoculation. Bedbugs appear to digest and destroy the bacilli. From the facts stated, with regard to the powers of comparatively rapid multiplication of the bacillus, its wide dissemination by the excreta and by animals and insects, it may be understood how extensively soil and habitation may become infected and how difficult it may be to arrest the ravages of the disease. The important part played by infection of a locality is strikingly shown by the rapid fall in the number of cases where an infected site is abandoned and the inhabitants placed in tents.

General Principles of Prophylaxis.—The most important safeguards against the development of plague are cleanliness of person and surroundings, good drainage, free ventilation, and a war of extermination against rats and mice. In addition, the prophylactic use of Haffkine's anti-plague serum appears to be of great importance. When the disease makes its appearance, the sick should be at once isolated in tent hospitals, and all who have come in close contact with them, or have been exposed to the same conditions, should be quarantined and kept under observation for ten days. The belongings and surroundings of the patient should be carefully disinfected. The sputum, urine, fæces, and dressings from suppurating buboes should be burned. Only healthy persons, free from abrasions, sores or ulcers, should be allowed near the sick; and such should be required to maintain scrupulous personal cleanliness and take a disinfectant bath once daily. The troops should receive abundant food and pure water; and the necessity for personal cleanliness and the frequent change of clothing impressed upon them. The use of well-fitting shoes and great care of the feet is necessary, since there is considerable evidence to show that inoculation usually takes place in the lower extremities. Soldiers should avoid infected districts, except under competent authority.

If proper care be taken, the liability of white troops to contract this disease appears slight. At Hong-Kong, in 1894, of 300 British soldiers who volunteered to assist in the sanitary policing of infected houses, but 10 contracted the disease; in Poona, in 1897, of over 900 white soldiers so engaged, not one became infected. In the latter instance the precautions taken included a hearty meat meal before beginning the work of the day; the retention in camp of all cases of slight ailment or those presenting cuts or abrasions; immediate disinfection by antiseptic solutions of cuts or bruises incurred during the work, and the thorough sunning of the clothing worn, for the rest of the day, after return to camp.

In addition to the destruction of rats, preferably by traps and ferrets, precaution should be taken to prevent infection by means of insect life. Such individuals as recover from the disease should be kept in quarantine for at least a month. Kitasato has found the bacillus of plague in the blood as long as three weeks after the beginning of convalescence.

The system of preventive inoculation against plague, as devised by Haffkine, has been carried out on an extensive scale in India during the past six years. As with cholera, the method has been systematically tested by inoculating a certain portion of the inhabitants of districts exposed to infection, leaving others uninoculated; and then observing the proportion of cases of the disease, and of fatal cases, among the two classes. The results have been distinctly successful.

At Poona, inoculation was practised with anti-plague serum on the native followers of the artillery troops stationed at that point. While everything was done outside of inoculation to prevent the spread of the disease, in 859 uninoculated there were nevertheless 143 cases with 98 deaths; in 671 inoculated there were 32 cases with 17 deaths. Had the inoculated, living under the same roof, belonging to the same families and sharing the same food and drink, been equally affected, the proportionate number of deaths would have been 77. The inoculation, therefore, reduced the death rate 77.9 per cent. In 1898, at Hubli, 3,815 persons not inoculated with anti-plague serum had 446 attacks, while 26,428 persons twice inoculated had only 31 attacks. If the latter had suffered proportionally as much as the non-inoculated they should have had 3,089 attacks. Such examples might be largely multiplied. In a statement published in June, 1899, Haffkine states that in the large number of inoculations made with anti-plague serum the difference in number of attacks occurring in inoculated and uninoculated was over 80 per cent., often approaching 90 per cent. The lowest in his experience was 77.9 per cent. The case mortality also was only half as great among the inoculated.

CEREBRO SPINAL MENINGITIS.—*Occurrence.*—No great epidemics of this disease appear to have occurred among troops, but the affection is one which prevails in all armies and is remarkable for the high mortality given by those affected. Sharp but distinctly localized outbreaks occur annually in all the larger armies; and in our own service cases of the disease were reported in all but six years of the period 1868–98. The affection may fairly be regarded as a camp disease; more deaths occurring in our army in the calendar year 1898, during the war with Spain, than had occurred altogether in the previous sixteen years of peace. For the period 1868–84 the death rate from this disease was .05 per thousand strength; for the decade 1885–94 it was .02 per thousand, while for the fourteen months, May, 1898, to July, 1899, the death rate was .70 per thousand. In the German army, during time of peace, the admission rates are much the same as our own under similar conditions, being given as follows:

Period.	Admissions per 1,000 strength.
1881–82 to 1885–86	0.06
1886–87 to 1890–91	.07
1891–92 to 1895–96	.08
1895–96 to 1897–98	.07

Among our troops the admission rate per thousand strength was .11 for the period 1895–98. In 1898, cerebro-spinal meningitis was the greatest factor in the total mortality of the Belgian army, amounting to .35 per thousand.

Predisposing Causes.—The disease is most common in individuals of the military age. Though want, privation and poor ventilation usually seem to predispose to the disease, there is abundant evidence to demonstrate that these conditions are not essential to its causation. The disease usually occurs during winter and early spring, although it may make its appearance at any time. For the period from May, 1898, to July, 1899, the death rate in our army from this disease was .13 per thousand strength during the month of January; about twice as high as in any other month of the period. For December it was .07; for June and July, 1898, it was .06 and .05, respectively. Hirsch, Notter and Firth, and others state that the disease is unknown in the tropics. During the period of fourteen months just mentioned, however, the death rate from this cause was .71 per thousand strength for troops serving in the United States; .34 for troops serving in Cuba; .16 for those in Porto Rico, and .26 for those in the Pacific islands. An epidemic of a most fatal type occurred on a transport at Casilda, in southern Cuba, during the occupation of that island by our forces. Of those attacked, all died within thirty-six hours. The epidemic abruptly terminated on sending the troops ashore.

Infection and Dissemination.—It is difficult to offer any satisfactory explanation as to the manner in which infection occurs or to the way in which the specific micro-organism is eliminated from the affected individual. Whether it enters the body through the alimentary or the respiratory tract, or through lesions of the integument, it is not possible to say. It is probably directly communicable from the sick in a mild degree only; but there is considerable evidence to show that the infection may be introduced into a locality by infected persons and things. Abbott and others are inclined to the belief that cases occurring during an epidemic are infected from some common source, and that they are predisposed to such affection by some unusual local condition. This opinion is supported by the fact that the disease shows no special tendency to progress along continuous lines or through contiguous localities. It has been known to appear in two regiments in a camp, while a third, located between the infected regiments, escaped. Love states that at New Orleans, in 1847, the disease attacked one regiment which was quartered in poor barracks, built on a damp soil and which was supplied with poor clothing, while an adjacent regiment, more favorably housed and clothed, escaped entirely. Depressing influences, whatever their nature, appear to be a predisposing cause.

Prophylaxis.—With present defective knowledge concerning this disease, it is difficult to formulate any rational scheme of prophylaxis against it. While rigid isolation of the sick has not been shown to be imperative, still this pecaution should invariably be taken in the military service. As with typhoid and measles, free ventilation should be assured, and no considerable aggregation under one roof of those sick with this disease should be allowed. As a not unreasonable precaution, all discharges and excreta should be promptly disinfected and accidental inoculation on the part of attendants guarded against.

As far as the troops are concerned, free ventilation, an abundance of good food, and the avoidance of fatigue should be included in the scheme of general prophylaxis.

DENGUE.—While dengue is not a disease which appears to be especially affected by the conditions of military service, our troops have suffered equally with the surrounding civil class during the epidemics which have from time to time occurred. Since dengue is a disease confined to tropical and sub-tropical countries, the only posts in this country which have been visited are those located in the south and southwest. During 1893 the affection prevailed in several garrisons. In 1894 the disease occurred at Fort Ringgold, attacking 154 men out of the 178 stationed at this post. In 1897 dengue appeared at Fort Sam Houston; 144 cases developing among the garrison of 522, and over 100 cases being treated among the families of soldiers and civilians at the post. During the same year the garrison at Fort McIntosh suffered also. Recently a large number of cases of this disease have occurred among our troops in Cuba and in the Philippine Islands, causing much temporary inefficiency.

The cause of dengue is unknown. Its outbreak is favored by high temperature and geographical location more than by any other factors; it occurring chiefly during summer and early autumn and being checked by frost. In its distribution, dengue closely resembles yellow fever. Overcrowding and filth appear to favor its occurrence. The mortality is small, and for soldiers otherwise in good health it may be regarded as *nil*. The disease, therefore, is only of importance as it incapacitates for duty. The specific cause of the affection is supposed to be given off in the saliva and excretions, and perhaps from the skin. Its incubation period is only a few hours, a fact which may explain its almost simultaneous appearance in large bodies of men.

Prophylaxis.—In the lack of knowledge as to the cause or means of spread of this disease, it is not possible to formulate definite plans for its prevention. Since the ubiquity of the virus is so great in this disease, the establishment of quarantine would scarcely be effective even if it were justifiable. The isolation of the sick, with the disinfection of all excreta, clothing and surroundings, might be practised, but would probably not be of any great value in checking an epidemic. It is fortunate that the disease is mild in type, is of short duration and leaves no after-effects—thus being of comparatively little importance to the military sanitarian.

DIPHTHERIA. —*Occurrence.* — Diphtheria is a disease which is of somewhat rare occurrence among soldiers. It is less common during active field service than in garrison, where it not rarely retains a foothold in old, badly constructed barracks for long periods, yearly outbreaks occurring during each season of cold weather. The disease is relatively frequent among troops living in casemates—though at Fort Yates it occurred for a number of years, despite every effort to the contrary, among soldiers quartered in old decayed log barracks. At the same post, the troops living in barracks of recent and more sanitary construction were rarely affected.

Figures for this disease show a somewhat lessened prevalence in our army as compared with those of England, France, and Russia. In the German army the admissions for diphtheria per thousand strength have been as follows:

Period.	Admissions.
1881–82 to 1885–86	1.2
1886–87 to 1890–91	.92
1891–92 to 1895–96	.93
Year 1896–97	.57

In the Austrian army, for the year 1897, only one case occurred for each 10,000 men. In our own service statistics would seem to show that the disease has of late years decreased in both frequency and virulence. Whether this is actually the case, or whether the reduction merely depends upon more accurate modern methods of diagnosis and treatment, is a question which cannot be definitely decided, but it is probable that both factors should be taken into consideration. During recent years, however, according to Coustan and Viry, the disease has steadily increased in the French army. In our own service the admissions for diphtheria, per thousand strength, since 1860, have been as follows:

Period.	Admissions per 1,000 strength.
1861-66 (civil war)	3.39
1868–84	.55
1885–94	.43
1895–98	.78
Year 1897	.43
Year 1898 (Spanish War)	.36

Dissemination and Infection.—The causative agent is transmitted from the sick in the discharges and secretions of the affected surfaces. In diphtheria affecting the throat and fauces the disease is transmissible chiefly through infected particles of mucus or flecks of membrane, which may be ejected from the mouth or nose by the act of coughing or sneezing. When the disease occurs among those in attendance on the sick, its origination is usually brought about by infection in this manner. It should be noted that the bacillus of diphtheria is very resistant to drying, and when dislodged from the throat in bits of false membrane it may retain its vitality for a long time. When such particles of membrane are dried and reduced to dust, infection may occur from the inhalation of air in which such dust is suspended. All clothing and other articles which have been in contact with the sick and upon which saliva has been allowed to dry may serve in this way to spread the infection. Abbott states that diphtheria bacilli have been found in the hair and on the shoes of nurses in a diphtheria ward, also on a broom used in the same ward. The bacilli may be inadvertently conveyed to the mouth after handling infected articles, and, in fact, any direct or mediate contact with the sick offers opportunities for infection. There is no evidence that the disease is ever transmitted by water. Milk, specifically infected during handling, has been known to give rise to diphtheria. Among the lower animals, cats may be affected with this disease. While diphtheria bacilli are capable of development on any mucous or abraded surface, for the military service infection may be considered to occur through the mouth and nose only. The period of incubation is difficult to determine; symptoms of invasion often appear within thirty-six hours after infection, but though they are rarely delayed more than four or five days, they may be absent longer and a quarantine of suspected cases for ten days is advisable. Convalescents from diphtheria should be regarded as sources of infection so long as the specific bacilli can be detected in the throat or secretions. The duration of infectivity appears to be, on an average, about thirty days, though it may be as long as three or four months.

Predisposing Causes.—Though widely diffused, diphtheria prevails chiefly in temperate and cold, damp climates. Low-lying districts, possessing a soil favorable to the development of microbes and rich in decaying organic matter, usually show a greater prevalence from diphtheria, especially if subject to the continued prevalence of cold winds with a high rainfall. In our army the disease is far less frequent in the southern garrisons. Its greatest incidence occurs in winter and early spring, probably largely through less free ventilation of barracks and the depressing influence of a vitiated atmosphere. The part long thought to be directly played by sewer gas in the production of diphtheria was undoubtedly due to accompanying influences of the above nature. Overcrowding is a factor of great importance in the spread of the disease, as is also inadequate sanitary police. Epidemic diphtheria, according to Klebs and others, has a well-defined relation to manure and compost heaps, in which the germs find favorable conditions for development. From this it would seem that the disease should occur more frequently among mounted troops, and such in fact appears to be the case. While figures for our own service are scarcely large enough for reliable comparison, it has been found by Longuet that in the French army, for the period 1872–85, the proportion of diphtheria cases among cavalry and infantry was in the ratio of ten to three. In the German army, 1874–82, diphtheria was more than three times as common among cavalry as among infantry. In general, persons who have been affected with diphtheria are especially liable to future attacks, as are those who suffer from acute or chronic inflammations of the pharynx or tonsils.

Prophylaxis.—In the prevention of diphtheria the provision of dry, sunny, well-aired barracks, free from overcrowding, is important. No accumulation of filth or refuse, and particularly stable manure, should be permitted in the vicinity. Dampness arising from the use of too much water in cleansing barrack floors should be avoided, as often producing tonsillar inflammation upon which a diphtheritic infection may be engrafted. Laveran regards the general use of antiseptic mouth washes by soldiers as of advantage during the prevalence of the disease. When the disease has actually occurred the sick should be at once isolated and clothing, bedding, and other articles which have been exposed to infection promptly removed and disinfected. The squad room of which the infected individual had been an inmate should be disinfected. All discharges from the point of diphtheritic invasion should be received into a strong germicidal solution, or on cloths, which are then burned. Soiled bed or body linen should be at once removed and disinfected before the secretions are permitted to dry upon them. When this is not practicable the soiled areas may be wet with strong disinfectant solution. The floor should be frequently mopped with a strong disinfectant solution; and the hanging of a damp sheet over the door leading into the room is of advantage. Eating utensils should be scalded after use and all uneaten remnants of food at once burned. On the part of the attendants great care should be taken to disinfect the hands after each manipulation of the patient. While attending to the patient a cotton mask, suspended so as to shield the nose and mouth and moistened with some antiseptic solution, may be worn to prevent possible infection from ejected mucus or membrane. Careful disinfection of the room and its contents is, of course, required after removal of the patient.

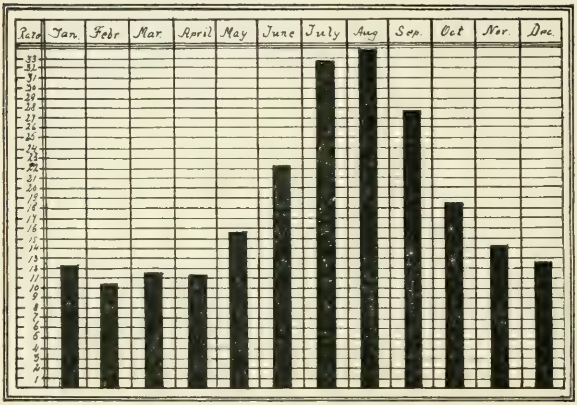

FIG. 1080. Distribution, by Months, of Cases of Diarrhœal Disease, per Thousand Strength, Occurring in the United States Army during the Decade 1875–84

Protective Inoculation.—In preventing the occurrence of diphtheria in those exposed to infection the most important prophylactic measure is that through which a condition of immunity is conferred by the subcutaneous injection of blood serum from an animal rendered highly immune to this disease. As the immunity thus produced is not permanent, lasting only from four to six weeks, the procedure should be employed only in the case of soldiers who have been presumably exposed to infection, or for the protection of such hospital corps men as are about to assume charge of diphtheria patients.

For immunization of those exposed to the infection of diphtheria an injection of 400 to 500 antitoxic units is usually sufficient.

DIARRHŒA AND DIARRHŒAL DISEASE.—Diarrhœa is ordinarily to be regarded not as an essential disease, but as symptomatic of an effort on the part of a healthy bowel to relieve itself of irritating contents or of some morbid internal condition. In the military service, however, the affection frequently prevails among a large number of persons at the same time and place, and by its severity, its tendency to become chronic, its refractability to treatment, and its undoubtedly infectious character, it may, under such conditions, be safely regarded as a distinct disease. Figures showing the prevalence of this specific affection are not available for our service, owing to the classification of all diarrhœas, whether symptomatic or essential, under the same heading. Further, in the medical reports of our army, conditions of this character, together with dysentery, are classed together as diarrhœal disease, and hence must be largely considered together. Under this heading they brought more men on sick report during the decade 1887–96 than any other class of diseases, the rate per thousand strength being 107.09. Field service largely favors their occurrence, and in nearly all wars they have been the most common class of affections. For the year of peace, 1897, in our army, the admission rate for all diarrhœal diseases was 73.77 and the death rate zero; while during the year of war, 1898, the admission rate was 303.76 and the death rate 2.14. These diseases are much more prevalent in hot climates than in the temperate zone, the admissions and deaths for troops in the United States alone, during the year 1898, being respectively 247.39 and 1.39 per thousand strength; while for those soldiers serving in the tropical islands the admissions were 551.54 per thousand, and the deaths 5.44.

For diarrhœa alone the average annual rate of admission, during the Civil War, was 608.84 per thousand strength; while the deaths from this cause averaged 13.70 per thousand. For the period 1868–84 the admissions for diarrhœa had fallen to 230.45, and the deaths to .26, per thousand strength. For the decade 1885–94 the admission rate was 109.65, and the death rate .02. For the year 1897 the admissions per thousand amounted to but 68.65, there being no deaths. For the year 1898, during the war with Spain, the admission rate rose to 274.49, but the death rate amounted to only .27 per thousand strength.

Diarrhœal diseases, in the temperate zone, are much more prevalent during hot weather, as is well shown by the accompanying diagram. Race is a matter of no small importance. While our colored troops are particularly susceptible to infection by dysentery, this is not the case with regard to simple diarrhœa, to which they appear to present considerable immunity. For the decade of peace, 1886–95, the admissions per thousand of white troops, for all diarrhœal diseases, amounted to 115.68; while for the colored troops during the same period the rate was 99.75. During the year 1897 the rates of admission were 75.78 for white troops and 52.22 for colored soldiers. During the war with Spain a proportionally much greater number of negro soldiers saw hard service than did those of the white troops, yet the admissions for the former were only 187.20 per thousand strength, while they amounted to 312.72 per thousand for the latter. Age exerts a marked influence on the occurrence of diarrhœal diseases; the rates for our service, at various periods of life, for the seven years 1890–96, being as follows:

Age.	Admissions per 1,000 of each class.
19 years and under	202.43
20 to 24	134.19
25 to 29	98.70
30 to 34	82
35 to 39	79
40 to 44	80.96
45 to 49	75.68

For the same seven-year period the admission rates for all diarrhœal diseases, per thousand strength, were thus divided among various branches of the service:

Artillery	133.35
Cavalry	113.29
Infantry	96.84
Medical Department	34.96

Diarrhœal diseases are much less frequent among officers than among soldiers.

As stated above, in many instances diarrhœa is undoubtedly infectious and capable of transmission to others by means of the excreta. No special micro-organism has been shown to stand alone in a causative relationship to the disease, and the latter may undoubtedly be produced by several forms of bacterial life. Diarrhœa prevails most in damp soils, especially when contaminated with organic matter. The diarrhœa prevalence and death rate are notoriously greatest among those whose resistive powers are impaired by malnutrition, exposure and fatigue. As with dysentery, chilling and sudden changes of temperature favor it. Foul air favors it, and want of ventilation and light are conducive to a high mortality. Density of population, as a factor in soil pollution, especially in camps, markedly increases the prevalence of diarrhœa. Food is closely concerned with the epidemic prevalence of diarrhœa, not only by predisposing toward it by causing digestive disorders, but also through its contamination with infectious material capable of directly provoking the disease. Bad water undoubtedly plays a prominent part in its causation, but probably not to the extent supposed by some. The cause of epidemic diarrhœa is undoubtedly transmissible by means of flies, and there is considerable evidence to show that air currents may be the means of its dissemination.

A distinction should be made between the epidemic diarrhœa indicated by the foregoing and those outbreaks of diarrhœa which not rarely occur among troops who have partaken of food in which certain putrefactive changes have occurred. In these cases the causative agent is usually a chemical substance, and the diarrhœal symptoms produced are merely those due to its properties as an irritant poison.

Prophylaxis.—The prevention of epidemic diarrhœa in the field depends upon the proper location of the camp, the absence of organic pollution of the soil, a pure water supply, the careful selection, preparation and storage of food, and the prompt disinfection of all excretal discharges.

While mild cases, in garrison, may probably be safely treated in quarters under most circumstances, in the field, where their infectious nature is suspected, such cases should preferably be removed to hospital for treatment; particularly since cases of diarrhœa may merely represent the early stages of infection with dysentery, typhoid fever, or even cholera. From the many causes through which diarrhœa may be produced, it is evident that no general rule can be laid down to cover all contingencies, but each case must be acted on independently, according to its merits, by medical officers.

DYSENTERY.—*Occurrence.*—Of all the diseases to which troops are subject on active service, especially in hot climates, dysentery is one of the most formidable and important; and this almost equally on account of its frequency, its severity, the difficulty of its treatment and its proportionately high mortality. The disease is one which is peculiarly favored by camp life.

History gives many instances in which dysentery has become epidemic among troops. It made frightful ravages in the army of Xerxes, in 480 B.C.; and it is recorded that in the invasion of Italy by Theodebert, in the year 538, one-third of his force died of this disease, compelling retreat. The army of Henry IV. was reduced three-fourths of its effective strength before the battle of Agincourt, through an epidemic of this disease. In 1773, half the English army at Hanau had dysentery, which decreased on the abandonment of the camp; and the same occurred in 1778 in the army of Prince William of Hesse. In 1757 the French army introduced an epidemic of this disease among the civil population of Mayence. In 1793 it ravaged the French army in Italy, and in 1812 in Poland. In Egypt, Napoleon lost more men from dysentery than from the plague. It prevailed largely during the Crimean War; and Laveran states that in three months there were treated, in the hospitals at Constantinople, 9,919 cases of diarrhœal disease—chiefly dysentery—of which 15 per cent. proved fatal. At Metz, in 1870, it was one of the greatest causes of mortality in the besieged army. In the military operations in our own country, it prevailed in the French war of 1756, and during the Revolution it became epidemic in the trenches before Boston. It was most extensive and fatal during the Seminole War in 1836; and the same was the case during the war with Mexico. During the Civil War period, July, 1861, to June 30th, 1866, the average rate of admission for dysentery, per thousand strength, was 120.88; the death rate for the same cause and period was 3.67. While the admission rate varied but little during these years, the mortality steadily increased; the death rate per thousand strength for this cause being 1.64 in 1861–62 and 6.31 in 1865–66. Since the Civil War, its prevalence in our country is shown by the following figures:

Period.	Admissions per 1,000 strength.	Deaths per 1,000 strength.
1868–84	29.04	0.59
1885–94	6.52	.10
1895–96	12.05	.68
1868–98	19.91	.45
Year 1897	2.39	. . .
Year 1898	28.39	1.86

The rates for dysentery in foreign armies in the present times of peace, like those until recently obtaining in our own service, are low. Among the British troops stationed in the United Kingdom during the decade 1888–97, the admissions per thousand strength amounted to .5, the deaths to .2. For the year 1898 the admissions amounted to .7, the deaths to .03. The occurrence of dysentery in the German army is shown by the following rates:

Period.	Admissions per 1,000 strength.
1881–82 to 1885–86	1.4
1886–87 to 1890–91	.24
1891–92 to 1895–96	.31
Year 1894–95	.25
Year 1895–96	.57
Year 1896–97	.10

The milder cases are not taken into hospital and do not figure in the above rates for the German army.

In the Austrian and Russian armies the rates of admission, per thousand strength, have been as follows:

Year.	Austrian Army.	Russian Army.
1892	4.1	3.4
1893	1.3	2.1
1894	1.3	2.0
1895	1.2	2.3
1896	.8	1.6
1897	.6	1.7

The case mortality among the Russian and Austrian armies during the above period was twice as high as in our own military service or those of England and Germany.

Nothing more clearly shows the value of modern military hygiene and sanitation than the great and progressive reduction of the rates for dysentery, which has occurred in all armies in the last two-score years. Not only has the proportion of admissions been largely decreased, but the case mortality has been reduced to an even greater degree. In our own army the vast improvement—as well as the favoring influence of field service on the occurrence of this disease—is shown in the chart (see Fig. 1081). For the French army in Algeria it is stated by Coustan that in 1847–48, out of every 1,000 deaths from all causes, 403 were from diarrhœa and dysentery, chiefly the latter, while for the period 1867–78 this disease occasioned but 72 deaths out of each 1,000; and the rate has fallen progressively since that time.

Predisposing Causes.—Dysentery occurs both endemically and epidemically in all climates, but is especially prevalent in the tropics. For the decade 1888–97 the admissions for this disease, among British soldiers in India, China, the Straits Settlements, Ceylon, West Indies, Egypt and Cyprus, and Mauritius, amounted to an average of 15.17 per thousand for all; while for the United Kingdom they were but .5, and for Canada .1 per thousand. In our own army, for the fourteen months, May, 1898, to June, 1899, inclusive, the death rate from diarrhœa and dysentery is given as 1.3 per thousand of troops serving in the United States; 5.69 for those serving in Cuba; 2.08 for those in Porto Rico, and 2.48 for those stationed in the Pacific Islands. For the last six months of 1897 the admissions for dysentery in the Spanish army in Cuba amounted to 72 per thousand strength, and the death rate to 10 per thousand strength. In temperate climates, summer is the season when the disease, like all diarrhœal diseases, prevails to the greatest extent; in the tropics it occurs most frequently at the close of the rainy season. Few facts in connection with the relation between dysentery and climate or season are more clear than those which indicate the influence of vicissitudes of temperature, and exposure to chilling, in determining attacks. The reduction of dysentery which has occurred in the French army has been thought to be largely due to the provision of conveniences which render unnecessary the chilling of the soldiers at night while attending to the calls of nature.

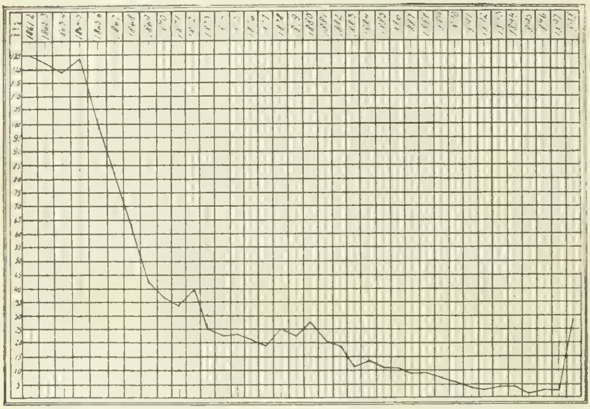

FIG. 1081. Admissions for Dysentery in the United States Army, per Thousand Strength, for the Period 1861–98, Excluding the Year 1867.

Dysentery, though sometimes occurring in dry localities, manifests a decided preference for damp and waterlogged soils. Of great importance in its epidemic occurrence is the saturation of the camp site with organic, and particularly fæcal, material. The destructive epidemics of former times undoubtedly depended largely upon long occupancy of camp sites, resulting in fouling of both soil and water. All cachectic states of the constitution powerfully predispose to dysentery. Scurvy and malaria are no exceptions to this rule, and the latter gives rise to a form of the disease peculiarly resistant to treatment. Fatigue, exposure, hardship, and anxiety also appear to have no small influence in determining its occurrence. A faulty dietary, especially as found in insufficient, coarse, or improperly cooked food, green or over-ripe fruits, an excess of salt meats, or the over-use of alcoholics, notoriously favors the disease. These points were particularly well shown in the happy change in the condition of the British army at the Crimea, in respect to dysentery, as soon as its wants as to diet, shelter and clothing were properly satisfied. A large number of outbreaks of dysentery have occurred during the prevalence of typhoid fever, the development of both diseases apparently being favored by the same general conditions.

Dysentery is particularly liable to affect young soldiers through their disregard of matters of hygiene and probably greater individual susceptibility. Tripler states that during the war with Mexico the death rate from dysentery was twice as high in the newly raised troops as in the old army. Negro troops appear particularly liable to contract dysentery. In our own service, for the decade 1879–88, the rates per thousand strength were as follows:

	Admissions.	Deaths.
White troops	13.65	0.20
Colored troops	29.65	.32

Among the British troops stationed in the West Indies, for the decade 1888–97, the rates for European troops, per thousand strength, were 6.9 for admissions, and .33 for deaths. For the same period the rates for non-European (negro) troops were respectively 16.8 and .44. Coustan, on the other hand, notes an immunity to this disease among the natives of Northern Africa, citing an instance where "a French column in Algeria suffered severely, while the native Arab followers, who set every law of hygiene at defiance, escaped sickness." From the greater care which they are able to give themselves, and also owing to their greater attention to sanitary detail, officers are much less liable to dysentery than are enlisted men.

Method of Infection.—The commonest recognized portal of infection is the mouth; the specific exciting cause of the disease gaining entrance in contaminated water or on uncooked foods on which the organism is located. Experiments show that infection can occur through the rectum, but this is undoubtedly a rare mode in human beings. The instances in which outbreaks of dysentery have been traced to the use of foul water, particularly that contaminated with fæcal matter, are very numerous; and of all causes contributing to the occurrence of this disease, that of impure water is the most important. In most instances this fluid merely serves as a vehicle for the introduction of the specific cause into the system, but it may at times, through suspended particles, have a predisposing influence through its irritative action on the bowel.

Prieur has reported an epidemic of 315 cases of dysentery occurring in 1891 in a small garrison in the French army, which he regards as directly traceable to the use of the common latrine by the first patient, who, as the affection became more advanced, was unable to keep from voiding his discharges on the floor and seats. No case appeared until six days after the first case was well developed. He believes that the affection was directly due to the dysenteric discharges being mixed with the dirt on the floor of the latrine and being carried into barracks on the shoes of the soldiers. The food of the latter was then contaminated with this infectious material; a result rendered very possible by the absence of mess rooms in French barracks and the fact that the soldier of that service usually sits on stairways or on the floors of halls or barrack rooms while eating his food.

Prophylaxis.—This is naturally dependent on the etiology. All drinking-water should be protected from contamination, and, when open to the slightest suspicion, should be sterilized by heat. It is well to keep in mind that if pure water be not provided in a hot climate, the men will get it from any source, however impure. Food should be carefully watched in respect to its sufficiency, quality, and the thoroughness of its cooking When an epidemic of the disease threatens, all raw fruits and vegetables should be excluded from the diet; and, if possible, hard bread and beans also, since these are difficult of digestion and irritating to the intestinal canal. Chilling, especially of the abdomen, should be avoided, and the use of the flannel band may be advisable. The camp site should be dry and well drained. If the disease appears with any severity the camp should be promptly moved without waiting for further developments. Instances have been known where regiments were affected with dysentery every time they encamped on a certain space, and old camping grounds notoriously favor the occurrence of this disease. The camp should be carefully policed to limit the fly plague, and the contents of latrines disinfected and covered twice daily. If possible, the excreta should be burned. Great care should be taken to prevent contamination of the water supply with fæcal matter, either from the location of the latrines or from uncleanly habits on the part of troops. Dysentery patients should preferably be removed from the locality in which the disease was contracted. Inasmuch as dysentery occasionally spreads in military hospitals where large numbers of such cases are under treatment, the necessity of free ventilation, abundant air space, and the prompt disinfection of the stools, bed pans, commodes and enema tubes are matters of the first importance.

Epidemic Influenza.—*Occurrence.*—In the military service, influenza is chiefly of importance through the incapacity for duty which it produces. The military age does not include the extremes of life, at which the disease is most fatal, and hence the mortality directly resulting from this affection is small. That it exerts an unfavorable influence in the production of secondary pneumonia and tuberculosis, however, there can be no doubt, though this is not shown by statistics. The disease in our army has occurred in well-defined epidemics of great intensity but short duration. During recent years these epidemics have occurred with much greater frequency. Following their subsidence there appears to have been a tendency on the part of medical officers to confound simple respiratory catarrhs with this disease, even in the absence of any epidemic tendencies, thus probably unduly raising the rates for this affection. During the Civil War the admission rates for influenza, per thousand strength, amounted to 60.84. For sixteen years, 1868–84, the cases fell to an average of 9.39 per thousand strength. During the decade 1885–94, epidemics in 1892 and 1893 greatly raised the figures for this disease, making the admissions 49.88 per thousand strength. For the period 1895–98 the admission rate was 44.92. For the year 1897 the admissions were again increased to 74.35; while for 1898 they fell to 32.37. In foreign armies the disease has prevailed among troops during the widespread epidemics which have from time to time occurred. In 1892 and 1893 high rates for this disease were given in all European armies. In the English army the disease has prevailed nearly every year since 1889. In the Russian army influenza appears annually as a potent factor in elevating the sick rates.

Dissemination and Infection.—The powers of resistance of the specific organism appear to be of a very low order. Pfeiffer found that dried cultures of influenza bacilli kept at the ordinary temperature were usually dead in twenty hours, and that no growth could be obtained from influenza sputum at the end of two days. Their duration of life in ordinary water is also short, death usually occurring in two days. From these experiments, Pfeiffer concludes that outside the body the bacilli cannot multiply under ordinary conditions and can remain alive but a short time only. The mode of infection in the disease he accordingly considers to be chiefly by direct contact with infective mucus, with which the bacilli probably alone escape from the organism. Its rapid spread over large areas was long thought to be explainable on the supposition that the infection was air-borne, but this is probably due to the combined effect of a short incubation period, an early infectiveness, a widespread susceptibility, and the existence of early unrecognized cases. It is impossible to say what are the conditions that favor its development and spread, but atmospheric conditions which favor bronchial irritation certainly play a part. The incubation period is from two to six days, and perhaps at times the limits are wider. Infectiousness commences early, in many instances before the disease has fairly declared itself. It persists for some time after acute symptoms have subsided, judging by the presence of Pfeiffer's bacillus. While this bacillus appears to be unable to cause influenza in the lower animals, there is abundant evidence that certain animals suffer with symptoms much like those of influenza during epidemics of this disease. During the epidemics of 1892 and 1893, in our army, the disease known as "pink-eye," regarded by many as a form of influenza, was extremely prevalent among cavalry horses.

Prophylaxis.—Influenza is an infectious disease, the spread of which can be checked by isolation; but when the peculiar features of the disease and the conditions of military life are considered, it must be admitted that isolation has its limitations and can usually only mitigate rather than entirely prevent an epidemic. In general, however, it is important as far as possible to prevent the contact of the infected with the uninfected. Soldiers affected with the disease, even in a mild form, should be taken into hospital, not so much for their own benefit as in behalf of others. While the disease prevails, large assemblages should, as far as possible, be avoided. There should be an avoidance of all influences which lower the general tone, and good ventilation and cleanliness of persons and surroundings are of value. The sputum of affected individuals should be treated in the same manner as if it were tuberculous. All handkerchiefs, napkins, bedding, clothing, and other articles used by the sick should be disinfected; though when an epidemic is once fairly established, the infection is so widespread that efforts looking to the control of the disease are of but little avail.

Malarial Fevers.—*Occurrence.*—Malaria has ravaged armies in every age and climate, and has frequently modified military operations or brought about their failure. Rome was saved from capture by malarial fevers, which so scourged the besieging Gauls under Brennus as to cause their retreat. In the year 208 the Roman army in Scotland lost 50,000 men, out of a total of 80,000, from this cause. No military disaster caused by malarial infection was ever more complete than that of the British expedition to the island of Walcheren, in 1809. On this occasion it has been said that the British were conquered before the battle. Out of an effective force of 39,219 there succumbed to the fever, between August 28th and December, no less than 23,175 men. After the return to England there were 11,503 additional cases. But 217 men, during this disastrous expedition, were killed by the enemy. In the Seminole War, in Florida, our troops suffered severely from malarial infection. In the French army before Sebastopol there were 20,623 cases with 2,179 deaths. In the Union forces, during the Civil War, there were 1,314,744 cases of malaria with 10,062 deaths, giving a mortality of 3.92 per thousand strength. "But though the mortality from these fevers was comparatively light, their influence in detracting from the efficiency of the army was very great," as well as largely influencing the rates of discharge for disability on account of resulting anæmia and chronic malarial poisoning. The so-called "Chickahominy fever" was particularly severe in its effects. Malarial fevers prevailed in the French army during the Italian War in 1859, and during the occupation of the papal states. Ashmead states that from 5,995 Japanese soldiers sent to Formosa in 1873, there were 6,105 admissions to hospital for pernicious malarial fever during a single year. In the French expedition in Madagascar, in 1895, out of a total force of 22,850 men—soldiers and carriers—there were 7,498 deaths; a mortality of about 33 per cent. Nearly all these deaths were from malarial fevers. During this expedition, with its enormous mortality, only 7 men were killed and 94 wounded by the enemy. In the same year a Spanish expedition in the Philippine Islands was scourged with malarial fever. During the last insurrection in Cuba the Spanish forces were largely depleted by malarial fevers of a severe type; the admissions to hospital for this cause, during the year 1897, amounting to 420 per thousand strength. In 1898, after the capture of Santiago, one-half of our forces in Cuba were at one time incapacitated for duty by reason of malarial fever. This grave condition of affairs evoked an appeal to the War Department, signed by all the higher officers, urging an immediate removal of these troops to a more healthy locality and using the sentence: "This army must be moved or perish."

Until within a comparatively recent period, malarial disease, in time of peace, constituted the prime factor in the constitution of the sick reports of our army. To-day it occupies a minor position for troops on the home station except for a few posts, the decrease not only having been great but steadily progressive. This reduction has been brought about by the withdrawal of troops from more unhealthful stations and by greater attention to sanitary detail at the few malarial posts at which military necessity requires garrisons to be maintained. During the last quarter of a century, also, the disease—especially in the eastern portion of the United States—appears to have considerably decreased in frequency and virulence. The possibility of retaining troops at stations on the Potomac river, as an example, was long a matter for serious consideration. At Fort Myer nearly all the garrison contracted malarial fevers during the season; of Washington Barracks it was at one time officially reported that during the malarial months there were scarcely enough well men to perform guard duty; and at Fort Washington the prevalence of malarial fevers resulted in the abandonment of the post as a station for troops for a number of years. These posts still lead all other stations in the army as regards malaria, but the number of cases of malarial infection are now very greatly reduced. Following the regarrisoning of Fort Washington, the sick rates at that station have been by no means seriously high. Since the Civil War the admissions for malaria for the entire army, per thousand strength, fell from 793.75 in 1868 to 78.88 in 1897. For the period 1868–84 the admission rates per thousand strength amounted to 331.06; for the decade 1885–94 they were 92.27. The influence of war, and especially the exposure to malarial infection in the tropics, caused an increase to 694.60 in 1898. The death rate, too, was unusually high during the last-named year, showing the more grave nature of the tropical infections. As far as the United States itself was concerned, the board investigating the occurrence of typhoid fever during the war with Spain came to the conclusion that malaria was a comparatively rare disease among those soldiers who remained in this country. As great as has been the reduction of malarial disease in our own army—to one-tenth of former rates—the improvement in this respect in the German army has been even greater. Official figures for the German army are as follows:

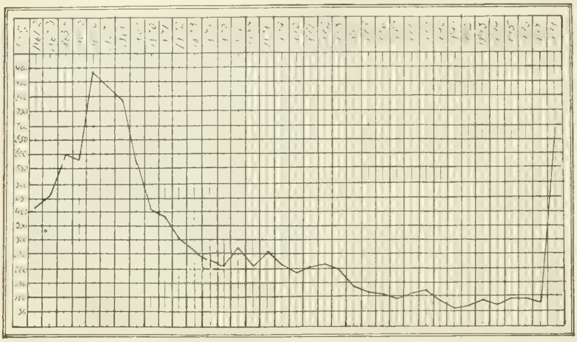

FIG. 1082. Admissions for Malarial Infections in the United States Army, per Thousand Strength, for the Period 1861–98, Excluding the Year 1867.

Period.	Admissions per 1,000 strength.
1881–82 to 1885–86	14.2
1886–87 to 1890–91	4.1
1891–92 to 1895–96	1.1
Year 1895–96	.55
Year 1896–97	.45

In the French army the admissions for malaria, per thousand strength, are thus given by Coustan for troops in France and Algeria:

Period.	Admissions per 1,000 strength.
1875–79	30.0
1880	18
1881	25
1882	30
1883	56
1884	15
1885	20
1888	13
1889	16
1890	17
1891	36.1
1892	24.4
1893	14.2

For the British troops on home stations the admissions per thousand strength, for the decade 1888–97, amounted to 6.3. For the year 1898 they were increased to 9.5. In the Russian army the admission and mortality rates from malarial fevers, per thousand strength, have been as follows:

Year.	Admissions.	Deaths.
1890	102.3	7.1
1891	79.9	.05
1892	78.1	.08
1893	79.1	.07
1894	57.6	.08
1895	44.5	.06
1896	46.5	.08
1897	47.3	.07

In the Austrian army the cases of malaria amounted to 50.3 per thousand in 1885; to 30.6 in 1891; to 40.4 in 1892; to 34.7 in 1893; to 28 in 1894; to 26.1 in 1895; to 22.6 in 1896; and to 31.9 in 1897. The deaths from malaria per thousand strength have recently been as follows in the Italian army:

Year.	Death rate.
1893	0.13
1894	.10
1895	.12
1896	.12
1897	.08

Manner of Infection.—Since the malarial parasite has not been observed outside the body, and nothing is known concerning its extra-corporeal existence, it is impossible to speak with certainty as to all the modes of its entry into the system. This very probably occurs in several ways. It has recently been advanced by some that the disease is directly transmitted from man to man only by inoculation, the mosquito serving as the intermediate host and transmitting agent by which infection is brought about. This claim, however, clearly lacks substantiation.

It is a matter of common observation that the infecting organism of malaria must multiply indefinitely outside the body independently of man. In fact, malaria is most prevalent where man is not, and where human beings, through the prevalence of this disease, cannot maintain an existence. Therefore this extra-corporeal multiplication must demand something more than a short cycle from man to mosquito and mosquito to man. Where this extra-corporeal life of the malarial parasite is spent has not yet been scientifically demonstrated, but both analogy and common experience point to water as necessary to its existence. The parasite in the blood is polymorphous, and in the flagellated variety it presents a type well fitted to pursue an independent existence. In water it may assume other and unknown forms quite capable of invading the organism through the walls of the alimentary tract. Certainly this is possible to other somewhat similar forms of life, as in dysentery, and there is much evidence of a practical nature to show that a malarial infection may actually be contracted in this way. Both Manson and Laveran believe that water in which infected mosquitoes have died may cause the disease.

Military history is full of instances in which outbreaks of malarial fever have occurred apparently as a result of the use of impure marsh water, and under circumstances which leave little possibility for infection by other means. As a type of these examples may be mentioned the well-known outbreak of malaria among the French troops on the ship *Argo*, and, like other similar instances, never yet disproved. Further, military history presents many cases in which the rates for malarial fevers were greatly diminished on the substitution of a pure for an impure water supply. In our own service the following instances may be mentioned: Fort Brown, in 1889, had an admission rate for malarial fevers of 1,675.86 per thousand strength, with a rate of 38.58 for constant sickness. Distilled water from the ice-machine was then provided for the use of the troops, and the rates for 1891 became 325.91 and 8.32, respectively. In 1892 the admission rates became 16.13 per thousand strength, and the constant sickness .35. The rates for this post have never returned to even a small fraction of what they were before the introduction of distilled water, and Fort Brown has ceased to be regarded as one of the malarious stations in the army. At Fort Ringgold the admissions for malarial fevers amounted to 2,304 per thousand strength in the year 1885. Distilled water was supplied for the use of troops—though its exclusive use was not compulsory—and in 1889 the rates had fallen to 562 per thousand strength. At this time there was considerable field service among the troops stationed at Fort Ringgold, and the post surgeon reported that he believed every case of malarial fever could be traced to an infection acquired outside the post. In 1897 the admissions for malarial fever at Fort Ringgold amounted to but 89.42 per thousand strength. In the experience of the writer, at Jefferson Barracks, the soldiers of that station were severely affected with malarial fevers. On the introduction of boiled water a marked reduction in malarial affections was apparent. Among the officers and their families at this station, who were careful to drink boiled or imported spring waters only, not a case occurred save in two children, who were shown habitually to use water from impure and unauthorized sources. Later, at Washington Barracks, it was observed that among the two batteries of artillery, who drank unfiltered water, the proportion of malarial cases was four times as great as among the men of the Hospital Corps Company of Instruction, having an average strength of about 150 men, who drank only water passed through Berkefeld filters.

Such instances as the above may be largely multiplied, and serve to emphasize the fact that, however else the malarial organism may gain access to the system, its entrance by means of the water supply should never be disregarded by the military sanitarian. Grawitz has shown, in connection with the infection of malaria by mosquitoes, that the disease is most common in the German army during spring when mosquitoes are not especially active, and he regards a water supply above reproach as a necessity in preventing malaria. It is true that a number of experiments have been made in the attempt to cause malarial infection by way of the alimentary tract. Healthy persons have been allowed to drink the water from supposedly malarious marshes; enemata of similar waters have been given to other individuals, and even the blood of malarial patients has been drunk by uninfected persons. These experiments were negative in their results. In the absence of positive knowledge that the water contained malarial organisms in the proper stage of development, the first experiments prove nothing; as for the experiment with the infected blood, it may well be that in this intra-corporeal stage the parasite has little powers of resistance against the digestive juices. In the light of the instances above quoted it may fairly be assumed that some important factor present in natural infection was inadvertently omitted from the experiments. On the other hand, besides abundant experimental evidence to the contrary, the theory that malaria is transmitted by water alone is refuted by the fact that men on board ships anchored off a malarial coast, who may not have been on shore and have used nothing but distilled water, often contract malaria. There is a very general impression that infection can occur through the respiratory tract, though in the absence of definite knowledge concerning the life of the malarial parasite outside of the body, it is evident that this point is not susceptible of absolute proof. Sleeping on the ground, where the emanations of a supposedly malarious soil are inhaled during repose, has long been thought to favor the prevalence of the disease among soldiers. It should not be forgotten, in this connection, that a wind which serves to carry a so-called malarial miasm may also carry insects serving as hosts for malarial parasites.

As a result of modern investigation, the occurrence of the disease through inoculation by infected mosquitoes has been scientifically demonstrated, and it appears probable that the organism frequently gains access to the blood in this manner. It has not, however, been shown that mosquitoes in a known malarial district harbor this parasite except after sucking the blood of an infected individual; and what part they play, if any, in the origination of the first cases of the disease occurring in individuals penetrating a previously uninhabited region has not as yet been worked out. That healthy persons may be directly inoculated by mosquitoes which have sucked the blood of a diseased individual there is no doubt.

Predisposing Causes.—Excluded from the Arctic zone, malaria appears to increase in frequency and virulence as the equator is approached, but this progression lacks both constancy and uniformity and does not exactly correspond with the isothermal lines. Certain tropical countries, like Australia and New Caledonia, are free from these fevers. In the island of Réunion, where it was formerly unknown, it has recently appeared, presumably imported by French troops from Madagascar, and now, according to Manson, it causes one-third of the deaths from all causes. In general, however, the disease bears a close relationship to warm climates, and of late years high mortality from malaria has occurred only in the tropics. In this country the rates for malarial disease are greatest among troops stationed in the southwest and in the Mississippi basin, although the few posts on the Potomac river are notoriously malarial. During the Civil War, statistics gathered by the sanitary commission showed the number sick from malaria per thousand to be proportioned as follows:

In northern posts at a distance from the sea and great lakes, 151; in the lake region, 193; at seaboard stations, Delaware capes to Savannah, 370; on the lower Mississippi, 383; in Eastern Florida, 520; in the southwest, 747.

Among our troops now stationed in Cuba and Porto Rico the rates are high, but in the Philippine Islands the rates for malaria have been unexpectedly low. For the world at large the present distribution of malarial disease, as affected by climate, is well shown by the following figures, per thousand strength, for the British army.

Station.	YEAR 1898.			DECADE 1888–97.		
	Admissions.	Deaths.	Constantly sick.	Admissions.	Deaths.	Constantly sick.
United Kingdom	9.5	..	0.37	6.3	0.01	0.23
Gibraltar	4	....	.25	7.2	.02	.24
Malta	152.1	0.11	4.17	14.1	.08	.66
Canada	...	..	.	1.3	....	.05
Egypt and Cyprus	58.4	..	2.19	21.9	.02	.85
Bermuda	...	...	....	1.9	....	.08
West Indies	78.5	3.87	4.13	62.2	.06	2.58
South Africa	39.2	.12	1.65	30.2	.08	1.23
Mauritius	380.3	1.22	15.76	579.2	2.76	25.74
Ceylon	71	...	2.28	93.0	.87	2.77
China	379.2	6.37	16.95	489.6	2.36	14.39
Straits Settlements	829.9	....	15.17	95.4	.64	3.18
India	434	.76	15.26	356.9	.71	12.01
West Africa	2,027.8	13.89	67.36	1,815.8	52.63	50.26

At certain military stations in India, malaria has at times been so prevalent that all drills and parades have had to be discontinued. In former times the death rate from this disease was often extraordinarily high. Davy mentions an instance in Ceylon where every white soldier sent to a certain station contracted malarial fever: out of a garrison of 254 men there were 205 deaths from this affection.

Next to climate, the influence of season appears to be of the most importance upon the occurrence of malaria; the rates for troops throughout the United States progressively attaining the maximum in September and the minimum in February, as is well shown in the accompanying diagram (see Fig. 1083).

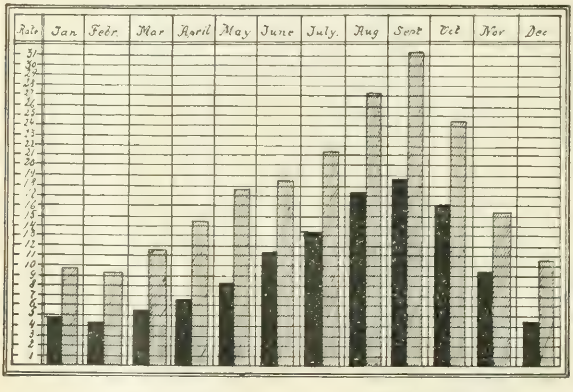

FIG. 1083.—Distribution of Cases of Malarial Fever by Months, per Thousand Strength, Occurring in the United States Army.

The relationship between malarial disease and marshy and swampy localities has long been recognized; though these fevers have been known to occur in localities not especially marshy, and, on the other hand, to be absent from regions wet and swampy. It must be admitted, however, that malarial affections are much more frequent on marshy coasts and low humid plains than on higher ground where drainage of the soil is more complete, and a certain amount of moisture in the soil appears to be essential to the development of the malarial virus. Marshes that are alternately flooded and partially drained of water offer conditions most favorable to the development of malaria. Under such conditions the profusion of rank vegetation, together with decaying organic matter, does much to favor it; though it may occur on barren, sandy soils with high ground water, particularly if the soil be organically contaminated. The broad, alluvial deltas of great rivers and the valleys of smaller streams, in warm climates, are usually malarious. The breaking or cleaning of new lands, in malarious regions, usually results in the appearance of malaria in the immediate vicinity, but by prolonged cultivation the disease becomes less frequent and severe, and may finally disappear altogether. The geological condition of a soil appears to play a somewhat important part in the production of the virus. An impervious surface soil, which does not readily become saturated but favors the rapid shedding of storm water, is not regarded as favorable to the development of the disease. A permeable, shallow surface soil with an underlying impervious stratum may favor the development of malaria under conditions of very moderate rainfall. In general, excessive or prolonged rainfall favors the occurrence of the disease. At high altitudes the disease disappears or becomes infrequent. In the tropics it is said that a height of more than two thousand feet is usually necessary to secure immunity. In the Philippine islands, however, our troops stationed in the upland valleys of the mountain districts suffered more from malaria, and from a more fatal type, than those in garrisons on the low plains of the coast, even the rice-field districts.

While troops may be attacked by malaria when on board ship, this is now rarely the case in practice. During the disastrous expedition of the French in Madagascar, in 1895, it is stated by Lemure that not a single fatal case of malaria occurred on board the thirty vessels constantly maintained off the coast; many other striking instances to the same effect have been recorded. There is a general conviction that the malarial virus may be carried by winds. In malarious regions near the coast the land breezes, especially if they traverse neighboring marshes, appear to favor the disease, while sea breezes do not. Many localities which might otherwise be highly suspicious, but which are continually wind-swept, are often free from the disease. Under ordinary circumstances the virus of malaria does not usually ascend very high above the ground; troops in upper floors of barracks may largely escape the disease where those on the lower floors contract it. There is, however, evidence that the malarial infection may sometimes be carried to high altitudes by strong winds blowing up narrow, unhealthful valleys. The recognition of the mosquito as an agent for the transmission of this disease has done much to explain the influence of air currents in carrying the disease; and the same may also be said with regard to the supposedly baneful influence of night air, since the malarial mosquito is not active during daylight. Davy says of certain British troops in Ceylon that they were largely exempt from malarial fever as long as they were employed by day only; so soon as they were employed more by night than by day, particularly in guarding convoys and the relieving of posts, fever became very prevalent and destructive. Of one company 70 strong, which was forced to sleep out in the jungle for a single night, he states that every man contracted fever and many died. Lemure gives an instance of a garrison of 50 French soldiers in Madagascar, of which at the end of two months

6 were dead, 12 had been invalided home, and all the remainder presented malarial infections. At the same time, the condition as to health was good among a body of marines doing similar duty at the same place, but who returned to their ship at night to sleep.

Experience shows that negroes native to and living in a malarious country possess an undoubted immunity to malarial fevers. This immunity, however, is lost to a considerable extent after long residence in a non-malarious climate, and does not exist to any very great extent among negroes native to regions where this disease does not prevail. The difference in respect to susceptibility between white strangers and native blacks is, however, great. In the British expedition up the Niger, of 145 whites and 158 negroes, there were 130 cases of fever with 40 deaths among the whites, while there occurred among the negroes but 11 mild cases, and these only in individuals who had passed several years in England. In West Africa, Great Britain has found it scarcely possible to retain white soldiers, and the garrisons are composed chiefly of native negroes. For the decade 1888–97 the admission rates for malaria, in West Africa, were 1,815.8 for the whites, in spite of special precautions taken to prevent their infection, and but 990.9 among the native negro troops; the death rates for the whites and negroes were 52.63 among the former and but 5.75 among the latter. In our own service, the rates during time of peace have been invariably higher among the whites than in the colored troops, although the difference was but slight as compared with the figures given above. During the war with Spain, however, the rates for colored troops were much higher than for the whites. This, however, is readily to be explained by the fact that the negro troops were nearly all engaged in the tropics, while many of the white soldiers, especially artillery and cavalry, were not moved from the United States, or in some cases from their usual posts. In our army the native-born white American appears to be slightly more susceptible to malarial infection than are soldiers of foreign birth. For the seven years 1890–96, the admissions for malaria per thousand strength amounted to 84.24 for American-born whites, 81.94 for soldiers of Irish birth, and 74.76 for those of German nativity.

As is the case with nearly all other diseases, age is a factor of great importance in predisposing to malarial infection, as is shown by the accompanying diagram. The desirability of detailing old soldiers for duty in malarious stations is obvious.

During time of peace, for the seven years 1890–96, the admission rates for malarial disease, according to the branch of service, were distributed as follows:

	Per 1,000 strength.
Artillery	163.24
Engineers	130.66
Cavalry	110.79
Ordnance	60.91
Medical Department	55.31
Infantry	46.28

Malarial fevers are much more common among soldiers than among officers. For the seven years 1890–96, the admissions in our army per thousand strength were 81.74 for enlisted men and 40.20 for officers.

Common experience shows that a considerable number of individuals, exposed to the malarial poison, escape infection. While this may be due to a racial immunity, as already mentioned, the strongest predisposing element in the development of infectious disease, to which malaria is no exception, is a lowering of vital resistance through unsanitary surroundings, bad food, exhaustion, or exposure. Among these factors physical exhaustion is not of the least importance, and in this connection Coustan calls attention to the fact that in the late Madagascar expedition the proportion of deaths among the French officers was 1:16.6, while among the soldiers, who were exhausted by the carrying of heavy burdens and long marching, the proportion was 3:5. Under-fed or fasting troops are very susceptible to malarial influences, and early morning drills before breakfast, or late guard duty, are especially favoring factors. Exposure to heat undoubtedly exerts an influence favorable to malarial infection, and the same is commonly believed to be the case with respect to alcoholic excesses.

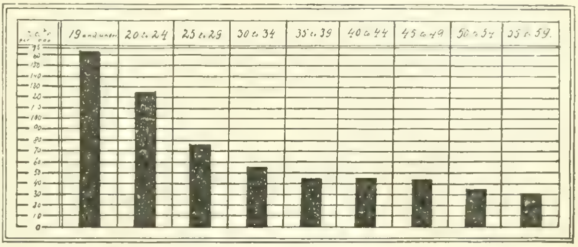

FIG. 1084.—Admissions for Malarial Fevers in the United States Army, Arranged According to Age, per Thousand of Each Class, During the Seven Years 1890–96.

The acclimation of troops in a malarious country cannot be counted upon—military experience showing that the mortality increases with the length of the sojourn. One attack of malaria, unlike the eruptive fevers, predisposes to another; and it is an invariable rule in the French service to select for expeditions in the tropics only such as have not previously been affected with the disease.

After residence in a malarious country, with or without symptoms denoting malarial infection, the disease often appears in a persistent form after removal to a region in which there is no malaria. This has commonly been observed in recruits sent from malarious stations to healthful districts in the west, and was particularly evident among our troops returned from Santiago.

Prophylaxis.—This depends upon the application of both special and general measures of prevention, and of these the former are probably of the most importance. In the avoidance of malarial infection by inoculation it is evident that troops should be shielded against the attacks of insects; further, that the insects should be destroyed. From the nature of military service it is obvious that soldiers cannot always avoid being bitten by mosquitoes, especially in the field. Much may, however, be accomplished to this end, and the less the number of bites the smaller are the chances of infection. In garrison all doors and windows should be provided with screens, and mosquito bars should be attached to all beds. The nets should be square, should be hung inside a framework, tucked carefully under the mattress all around and stretched tightly better to allow the passage of air. The mesh may be fairly large, but should be free from rents. Care should be taken to destroy all mosquitoes within the netting after entering. This is best accomplished by holding a light at one corner outside the net, toward which the insects fly and are readily despatched. In the field, in malarious districts, soldiers should be furnished with squares of mosquito net or head nets for use at night. The weight need not be more than a couple of ounces, and such a protection would conduce much to comfort and health and amply repay its carriage. In camps, smudges made of green boughs lighted to windward, so that the smoke blows over the men, are often of great value. For this purpose the eucalyptus boughs, where they can be obtained, are said to be particularly valuable, the mosquito having an especial antipathy to this tree. Oil of pennyroyal, or oil of cloves, smeared in small quantity over the exposed surface or dropped on the pillow, may keep off these insects, but being volatile, these substances require to be frequently renewed. In Italy, pieces of onion are often used for the same purpose. Mosquitoes which have gained access to barracks may be destroyed mechanically, or by the fumes from burning pyrethrum powder, tobacco, or even from green wood. The vapor of kerosene oil or turpentine also kills them. Leggings are an excellent protection for the ankles against these insects, but gloves or head nets can rarely be worn on the march. Still, except during night marches, malarial infections are probably rarely acquired under such conditions. Since patients suffering from malaria are capable of directly infecting others through the agency of mosquitoes, they should always be treated under mosquito netting; and this precaution should be continued for weeks after the actual fever has disappeared.

When mosquitoes are present in barracks, suitable conditions for their development are usually found close by. In the case of the malaria-carrying variety, these are small stagnant pools. Where these cannot be filled up or drained, recourse should habitually be had to culicides for the destruction of the larvæ and pupæ. For this purpose the substance most available for military use is kerosene or mineral oil. This should be sprinkled over the surface of the water, as with a broom, until a fine film is produced, which destroys the larvæ by cutting off the supply of air and choking their air tubes. The adult insects, which alight on the surface to deposit their eggs, are also destroyed. This film must spread over the entire surface of the water, and should last at least two days, to kill the larvæ as they are hatched from the eggs already laid. The quantity of oil required naturally varies with the conditions met with. For small, still pools probably one ounce of kerosene to each fifteen square feet of water surface is quite sufficient. Surface vegetation, sometimes very abundant, may often obstruct the mechanical action of the oil, and in waters even very slightly running the supply of the oil must be frequently or continuously renewed. Petroleum, also, has the disadvantage of evaporating somewhat rapidly in warm weather. Potassium permanganate will destroy the larvæ, but only in solutions having a strength of five parts to the thousand. Strong infusions of tobacco are fatal to the larvæ; and they are destroyed by powdered chrysanthemum flowers, as now found in commercial insect powders, in the proportion of three parts to the million. Recently, Celli and Casagrandi have shown that gallol, in the proportion of seven parts to the million, is the most certain and effective agent in destroying the larvæ and possesses the advantage of great permanency. Whatever be the method employed, the life history of the mosquito shows that it should be repeated at intervals of from seven to ten days. The introduction of small fish or minnows into fishless breeding-places of the mosquito is of great importance, as these feed greedily upon the larvæ and soon exterminate them.

General measures of prophylaxis have been shown by experience to be of much value in the prevention of malaria. It is not advisable to take an army into a malarious country during the fever season, and in localities where fevers prevail to great extent it is well to retire to high ground during the malarial period, as is done by the English in India and Jamaica and by the French in Guadeloupe. In locating a camp or post in a malarious district, special care should be taken in the selection of the site. In general, the appearance of the natives will give some knowledge as to the prevalence of this disease among them.

The abandonment of a highly malarious post, in time of peace, is much to be desired and can usually be accomplished. The retention of unhealthful posts is at the expense of unnecessary suffering, and in the past many thousands of lives have been uselessly sacrified to tenacity of position. With marching troops, zones of malarious country should be avoided or passed over as quickly as possible. The abolition of marshes by flooding or drainage, and the removal of adjacent shrubbery and rank vegetation are great prophylactic measures in reducing the amount of malaria in a garrison. Plants of rapid growth should be cultivated for the assistance which they give in removing moisture from the soil. For this purpose the eucalyptus, castor-oil plant and sunflower appear to be most satisfactory, not only drying the ground but being shunned by mosquitoes. Subsoil drainage is often of great value, but this can rarely be thoroughly carried out in the military service. Barracks should be raised on piers, be cemented underneath and be of two stories in height. All water used for drinking purposes should be sterilized by heat. Food should be abundant and nutritious. Distributions of hot coffee for those on guard at night, or engaged in arduous labor, are often of value. The use of quinine as a prophylactic, where troops are temporarily exposed to marked malarial influences, is of great importance, as has been repeatedly demonstrated. Not only are the cases of malarial infection greatly decreased in number by its use, but the character of the cases which occur is favorably modified. In general, a dose of gr. v. once daily will be sufficient, preferably taken shortly before any unusual exposure is anticipated. In a malarious country the general issue of a small dose of quinine, after anything lowering the resistive power, as a forced march, wetting, or lack of food, has much to commend it. In the Italian army, arsenious acid has been tried in the prevention of malaria, but with little satisfaction. Exposure, particularly to heat and night air, and over-exertion should be avoided. The soil should be disturbed as little as possible. If this should be necessary, as little as possible should be disturbed at one time and the work should not be begun too early in the day. The minimum number of men should be employed in the work, and only such as have not had a previous malarial infection.

MEASLES.—*Occurrence.*—Among troops, this disease is of frequent occurrence. Under certain conditions, when developed under conditions of want, hardship, exposure, and bad sanitation—and especially when associated with a scorbutic taint—the disease may assume an extremely severe and fatal character. Formerly the occurrence of the hæmorrhagic form of measles was not infrequent among troops, and was much dreaded. The exposure, often unavoidable, in the treatment of the sick in tent hospitals does much to develop secondary bronchitis and pneumonia; and to these latter causes are to be attributed also much of the gravity which the disease has assumed when prevailing among troops during the existence of hostilities. In garrison, the mortality from this disease is small; for the period of peace, 1885–94, in our army, the death rate was but one one-hundred-and-tenth of the rate given by the Registrar-General for the total population of England and Wales during the same period. From 1832 to 1859, according to Rosse, measles was the cause of 2.7 per cent. of deaths from all causes occurring in the garrison of Paris. During the Civil War there were, in the Union forces, 75,177 cases with 5,174 deaths, the admissions per thousand strength during this period amounting to 31.72 and the deaths to 2.02. Among the Confederate troops, Eve states that measles prevailed to such an extent that whole companies, battalions and regiments, under organization, had to be disbanded and the men sent home. During the siege of Metz, measles was extremely prevalent and fatal in the garrison. In our army, for the period 1868–98, there occurred a total of 3,733 cases with 15 deaths, giving an admission rate per thousand strength of 4.50 and a death rate of .017.

The disease appears to be more prevalent now than formerly among our troops, the rates being as follows:

Period.	Admissions per thousand.	Deaths per thousand.
1868–84	1.88	0.004
1885–94	4.85	.004
1895–98	13.72	.090

The expansion of our army with a large number of susceptible recruits at the outbreak of the war with Spain, and their aggregation in large camps where the dissemination of the disease was favored, did much to raise the rates for both admissions and mortality during the last period given above, the admissions for the year 1898 being 25.09 per thousand strength and the deaths from this cause amounting to 0.26 per thousand; while for the previous year of peace, 1897, the admission rate was only .82 per thousand, with no deaths. In the German army the rates of admission for measles, for varying periods, were uniformly low, as follows:

Period.	Admissions per 1,000 strength.
1881-82 to 1885-86	1.4
1886-87 to 1890-91	1.5
1891-92 to 1895-96	.83
Year 1896-97	1.1

For the French army the rates of admission per thousand strength, for the five years 1890-94, was 9.71. Coustan believes that the system prevailing in the French army, of turning into a common magazine for storage certain articles worn by the men only during the period of the field manœuvres, greatly favors the dissemination of the infection of measles, and hence partially explains the high rates given by that army. In the Austrian army, for the year 1897, the admission rate was only .8 per thousand, but the proportionate mortality was high, .02.

Colored troops appear to be less susceptible to measles than are white, but certain mild cases are more liable to escape recognition in the former class; the rates of admission in our army for measles, in 1898, were 25.91 per thousand whites and 14.42 for colored troops. During the Civil War the rates were 30.41 for white and 46.65 for colored troops, this excess as regards the negroes being apparently due to lessened efforts for the control of the disease among them. The disease occurs far more frequently among recruits than among old soldiers; in the Civil War the number of cases depending upon the proportion of susceptible individuals and occurring particularly among country-bred recruits. For the French army Coustan gives the following figures, as illustrating the effects of age and length of service on the occurrence of this disease:

Year.	Less than one year service, admissions per 1,000 strength.	More than one year service, admissions per 1,000 strength.
1891	23.63	12.69
1892	99.62	4.04
1893	11.98	6.08
1894	14.80	7.91

In our own service, measles prevails to by far the greatest extent at the recruiting depots; in 1892, the recruits at Columbus Barracks furnishing more than half the cases occurring in the entire army. The disease ordinarily occurs in time of peace most frequently during cold weather, when ventilation is comparatively restricted and the opportunity of infection is most favorable. During the year of war 1898, when the number of recruits was great, the rate of admission was by far the greatest during June and July, thus showing the greater importance of length of service as compared with season in influencing the occurrence of this disease. During the same year the admission rate was 19.82 per thousand among soldiers stationed in the United States, while there was a total rate of 48.25 for the troops serving in the West Indies and the islands of the Pacific. The case mortality of measles, as already noted, is capable of varying within very wide limits, ranging from as little as 1 or 2 per cent. in some outbreaks to 40 or 50 per cent. in others. "In Paris, during the siege (January, 1871), out of 215 of the Garde Mobile who took measles, 86, or 40 per cent., died; and the mortality reached very nearly the same figures among the French troops who returned to Paris after the Italian war, 40 out of 129 cases dying in one hospital whose sanitary condition was bad." As in typhus fever, the concentration of a large number of measles cases, with deficient ventilation, appears unfavorably to affect the course of the disease through an intensification of the virulence of the infection.

From analogy, it may be assumed that the cause of measles is a specific micro-organism, but as yet its special nature has not been determined. The infection is presumably given off by the breath and mucus from the catarrhal surfaces, also by exfoliated epidermis. The poison undoubtedly is capable of being air-borne and tends to cling to fomites and remain in illy ventilated spaces. The materies morbi is very tenacious of life; and where it once fairly establishes itself, as has been apparently the case at Columbus Barracks, annual epidemics are the rule. There is no evidence that the disease is transmissible by water or food; infection probably always occurs through inhalation. In a garrison, the disease is not infrequently introduced by children. The incubation period varies from eight to twenty days, the usual limit being about eleven days. The infective period begins with the earliest symptoms; it is greatest while the catarrh and rash are present, and probably extends well into convalescence. As a general rule, infection is over by the end of the fourth week, provided that cough and desquamation have ceased. One attack of measles usually confers an immunity to future attacks.

Prophylaxis.—In civil life, vigorous efforts are rarely made to prevent the spread of measles. In the military service the opposite should be the case, bearing in mind that this disease is never devoid of danger, and, particularly in the field, may assume a grave character. Further, it causes the loss of a considerable amount of service by troops to which the state is entitled. In view of the fact that measles was mild under favorable conditions and was often extremely fatal when the patients were exposed to inclemencies, it was seriously urged, during the Civil War, to infect all susceptible recruits with this disease, and only after recovery to send them to join their regiments. The prevention includes the isolation of the sick and the disinfection of all clothing, bedding, and surroundings. The discharges should be disinfected, particularly those from the mouth and eyes. For the latter purpose soft rags should be employed, and these burned after use. As far as the patient is concerned, Cameron concludes that "so far as figures are of value, ample air space, free draught, freedom from overcrowding and from effluvium nuisances, conduce most to recovery."

In the spring of 1898 the writer carried out some investigations with regard to the production of an artificial immunity against measles. The experiments were abruptly interrupted by field service, but appeared to be distinctly favorable so far as carried out. The method employed consisted in the subcutaneous injection of blood serum obtained from convalescents from measles by means of cantharidal blisters. The injections were made in children living in an infected garrison, 5 to 10 c.c. being administered in three doses at intervals of about forty-eight hours. None of the cases so inoculated contracted the disease, while a considerable proportion of the susceptible and uninoculated children became infected.

Mumps.—Mumps occurs very frequently among troops, especially in young soldiers, but its mortality is practically nil, and, like some other affections, it becomes of importance merely from the temporary disability for military service which it causes. In a total of 3,122 cases of mumps occurring in the United States army for the thirty-one years 1868-98 inclusive, there was not a single death which could be attributed to this affection. The admission rate for this disease for the period 1868-84 was 2.99 per thousand; for 1885-94, it was 5.08, and for 1895-98, it was 4.05. The rate of admissions for the entire period, 1868-98 inclusive, was 3.76 per thousand.

In the military service, mumps usually prevails in well-defined epidemics. A large proportion of the cases occur in recruits. The aggregation of such young men at certain stations for purposes of instruction is very favorable to the occurrence of this disease; and in 1894, out of 337 cases of mumps occurring in the army, there were 119 cases at the two recruiting depots of Columbus Barracks and Jefferson Barracks. In the previous year, out of a total of 149 cases, 43 cases occurred at the first-named station. Orchitis and atrophy of the testicle are very common among soldiers affected with mumps, being present in about one-third of the cases. Coustan states that in an epidemic among French soldiers in 1891, every man attacked developed orchitis. Laveran found it 211 times in 699 cases.

The infection is supposed to be given off by the breath and the secretions of the mouth, but as yet no specific organism has been isolated. It is not conspicuously disseminated by means of fomites; in garrison, it frequently appears to be introduced from outside by children. The period of incubation is reckoned as from fourteen to twenty-five days. The patient is regarded as infectious while there is any inflammation or tenderness of the salivary glands. Sanitary precautions consist in the isolation of the patient and the disinfection of his clothing and equipment. Beyond the cleansing and disinfection of the cuspidors in the squad room, no further preventive measures, in view of the comparative triviality of the affection, will usually be necessary. Among soldiers mumps not infrequently occurs in close association with measles, but this apparent relationship is probably to be regarded as accidental. The disease is most common during the colder weather.

Acute Croupous Pneumonia.—*Occurrence.*—Pneumonia is a disease which, as might be expected, considering the conditions of military life, though not one of the most common to which the soldier is exposed on service, is yet not of infrequent occurrence nor unproductive of considerable mortality. Though ordinarily the disease occurs only sporadically, at times it appears to take on a distinctly contagious character; and well-defined epidemics of pneumonia among soldiers, either in garrison or in the field, are by no means infrequent. Under such conditions it is reasonable to assume the existence of some common depressing influence, by which a number of individuals are predisposed to an infection, to which, under ordinary circumstances, they would be largely unsusceptible. In considering the prevalence of this disease in the military service, it should not be forgotten that pneumonia may either occur primarily or be consequent to some other disease, particularly influenza and measles; and it is particularly during epidemics of the latter affections that the rates for pneumonia attain their maximum. While the disease occurs to some extent among troops in garrison, it is considerably favored by the exposure incident to field service.

The rates in our army for pneumonia, since the Civil War, have steadily decreased as a result of the greater care given to the comfort and welfare of the soldier, as shown by the following figures:

Period.	Admissions per 1,000 strength.	Deaths per 1,000 strength.
1861–66 (Civil War)	32.45	7.79
1868–84	6.55	1.01
1885–94	4.28	.76
1895–98	3.66	.51
Year 1898 (war with Spain)	4.84	.83
Year 1897	2.96	.21

The case mortality of the disease has also greatly diminished, but this is probably due to a more rational line of treatment than to any decrease in the virulence of the infection. As compared with the rates for foreign services, those for our army are extremely low. In the German army the admissions and deaths from pneumonia have been as follows:

Period.	Admissions per 1,000 strength.	Deaths per 1,000 strength.
1881–82 to 1885–86	11.0	0.19
1886–87 to 1890–91	10.5	.43
1891–92 to 1895–96	9.3	.36
Year 1896–97	6.7	.25

It is seen that in the German army the death rate has latterly increased while the proportion of cases has diminished, a fact which can be explained only on the supposition of an increase in the gravity of the affection. In the Russian army the following are the recent rates:

Year.	Admissions per 1,000 strength.	Deaths per 1,000 strength.
1890	10.4	0.99
1891	10.2	.90
1892	8.7	.81
1893	10.7	.87
1894	7.7	.62
1895	8.3	.66
1896	7.7	.62
1897	6.4	.49

In the Austrian army, for the year 1897, the admissions for pneumonia, per thousand strength, amounted to 5.1, while the death rate was .49.

Dissemination and Infection.—The specific micrococcus of pneumonia discovered by Surgeon-General Sternberg, of the United States army, is found in the sputum of practically all persons suffering from this disease. It has also been found in acute peri- and endocarditis, acute pleuritis and empyema, acute meningitis, and otitis media. After death it may be found, in varying numbers, scattered throughout the body. It has been found to be constantly present in the mouth cavity of healthy individuals, and by some has been thought to be present in the mouth of every one at some time or other. While the micro-organism usually loses much or all of its virulence by artificial cultivation, its original qualities are retained in sputum, blood, and other pathological exudates for considerable periods, according to Abbott for as long as fifty-five days, even in the dried condition. It is not unlikely, therefore, that dried pneumonic sputum, when ground into dust and inhaled, may induce the occurrence of the disease in susceptible individuals. This condition of susceptibility is, however, essential. "There must be some predisposing cause, for the micrococcus is widely disseminated, and is often present in the mouths of healthy persons without producing any ill effect. Under ordinary circumstances the protective mechanism of the body prevents invasion." Since the micro-organism of pneumonia is so frequently present in the mouth, it is probable that the sporadic cases of the primitive disease so commonly seen are the result of auto-infection depending upon a lowered vital resistance. As the lungs are the seat of attack, it is probable that the infective organism gains entrance by the air passages, though there is some evidence that it may be brought to the lungs from distant parts by the vascular or lymphatic circulation.

Predisposing Causes.—Among the predisposing causes of pneumonia those of latitude and season are of importance; the disease being most common in cold climates and, as shown in the accompanying diagram, during late winter and early spring. The negro race appears to be especially susceptible to the disease; the rates per thousand for our own service, for the decade 1879–88, being 7.52 for admissions and 1.79 for deaths among the colored troops, and but 4.46 and .76 respectively, for the white troops. Among the whites, figures for the seven years 1890–96 showed the American-born to be about 20 per cent. more liable to contract the disease than soldiers born in Ireland, Germany or England. Age appears to be a factor of no small importance; soldiers under twenty-five years of age and over fifty years being more than twice as liable to contract the disease as those between twenty-five and thirty-five years of age. Among the several arms of the service the admission rates per thousand strength, for the period 1890–96, were 4.12 for cavalry, 3.46 for infantry and 2.95 for artillery.

Pneumonia is especially apt to follow upon exposure to sudden and extreme variations in temperature. Troops returning from service in the tropics, and especially such as are insufficiently clothed for the colder climate, are particularly liable to this disease. Wetting appears not infrequently to precipitate an attack, as do exhaustion and alcoholism. The disease often occurs in soldiers who, after having been exhausted by fatiguing exercise, expose themselves while sweaty to chilling draughts. Insufficient heating of barracks has been thought to favor pneumonia. Repeated outbreaks sometimes occur in the same buildings, especially in casemates. It is a matter of common knowledge that epidemics of this disease among troops often occur at the same time as epidemics of pneumonia or influenza in cavalry horses with whom the soldiers come in frequent contact.

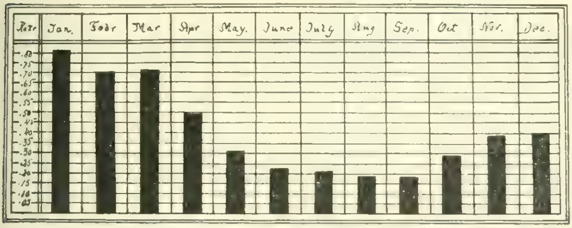

FIG. 1085.—Distribution, by Months, of Cases of Pneumonia Occurring in the United States Army, per Thousand Strength, During the Decade 1875–84.

Prophylaxis.—From what has been said, it is evident that measures having reference to the prevention of pneumonia among troops are particularly those which look to the maintenance of a high physical tone. Good and sufficient food, suitable clothing and shelter, rational exercise in the open air, cleanliness of person and temperate habits are all important. Chilling after drills and exercise should be avoided.

When pneumonia assumes an epidemic or infectious type the patients should be isolated. All the precautions required in the case of tuberculosis should be taken in this disease also. Attendants on pneumonia cases should be well nourished and have sufficient rest; it being borne in mind that by being overworked and in constant association with the patient they offer the conditions most favorable to their own infection.

SCARLET FEVER.—This affection can scarcely be regarded as a soldier's disease; being rare in our own army, though less uncommon in those of other nations. During the period 1868–98, there were reported in our service only 160 cases in a total numerical strength of 859,908 men. Of these 160 cases there were but 6 deaths. The disease occurs in garrison rather than in camp, there being but 12 cases during the year of war with Spain. Of these 12 cases, however, 3 were fatal, while of 148 cases occurring during the previous thirty years of peace but 3 succumbed, thus showing the unfavorable influence of the exposure unavoidably incident to treatment in field hospitals. The admission rate per thousand strength was .19 for the period 1868–84; .18 for the period 1885–94, and .21 for the period 1895–98. In the Austrian army, for 1897, the admission rate is given as .30 per thousand strength and the death rate as .01. In the German army scarlet fever has occurred as follows:

Period.	Admissions per 1,000 strength.
1881–82 to 1885–86	1.2
1886–87 to 1890–91	.95
1891–92 to 1895–96	.92
Year 1896–97	.66

Epidemics of scarlet fever have frequently occurred among children living at our army posts without the troops being affected. It usually occurs in late winter or early spring. The contagion of scarlet fever is probably not developed until the eruption appears, and is especially to be dreaded during desquamation, when the poison is spread by the fine particles of epidermis which are disseminated from the person. The morbific agent is very tenacious of life and may cling to rooms, clothing, and other articles for long periods, retaining its power to reproduce the disease under favorable conditions. The infection appears to be given off by the breath and the secretions from the nose, mouth, ears and kidneys. The disease does not appear to be spread by water, although infected milk appears to have caused several outbreaks. Infection is almost always contracted by inhalation. The incubation period is from one to six days; the quarantine required is usually from seven to nine weeks, or until desquamation is at an end. Prevention includes isolation of the sick as a matter of the first importance. The apparel, equipment and former surroundings of the patient should be carefully disinfected. All discharges should be disinfected before removal from the sick-room, and the arrest of contagious material from the skin secured by the application of some antiseptic ointment. The convalescent soldier should not associate with others until all desquamation has ceased, the process being aided by repeated bathing in warm soapsuds. Careful shampooing of the head is essential in securing disinfection of the person.

SMALLPOX.—*Occurrence.*—Until well within the past fifty years this disease has prevailed generally among armies, being regarded as one of the most common and at the same time most fatal affections to which troops were ordinarily exposed. Its prevention among soldiers by means of vaccination was not attempted until 1831, when this operation was introduced in the army of Würtemberg. Some years later it was taken up in other armies and practised with more or less thoroughness. During the Revolutionary War the failure of our invading expedition into Canada was largely due to a scourge of smallpox among the Continental forces. It was present during the war with Mexico, and during the Civil War there were 18,962 cases with 7,058 deaths. In the Confederate army of northern Virginia, from October, 1862, to January, 1864, there were 2,513 cases and 1,020 deaths. During the Franco-Prussian War the German troops, who had been carefully vaccinated, had only 278 fatal cases of smallpox in a total strength of 913,967 men; among the poorly protected French troops the deaths were said to have amounted to 23,400, and Coustan states that during the siege of Paris the mortality from smallpox among the besieged forces was no less than 6.76 per cent. In the military hospitals the German wounded escaped variola, where the French wounded prisoners were generally attacked. The lesson was not lost on the French authorities, and a vigorous system of vaccination was later instituted, so that 92 deaths from smallpox in 1877 were progressively reduced to 4 in 1890 and 3 in 1892. In the German army, excluding the Saxons and Bavarians, for the period 1873–74 to 1896–97, inclusive, there were but 17 cases of variola in a constant strength of over half a million men. Of these cases but 2 were fatal. In the Italian army of 204,312 men, for the year 1897, there were but 2 cases of variola; in the Russian army, for the same year, the admission rate per thousand amounted to .4. In the British army, for the period 1888–98 inclusive, there were no cases of smallpox among troops stationed in the temperate zone. In the tropics, however, the disease prevailed to no small extent; the admissions per thousand strength being 1.1 for

China, .8 for India, and 1.7 for Egypt and Cyprus. This difference was undoubtedly due to the general dissemination of the disease among an unprotected native population. In our own army, for the thirteen years 1885–97, there occurred but 6 cases of smallpox, and in these instances the fact of previous vaccination could not be determined. In the year 1898, however, our troops on foreign service were brought into contact with an unvaccinated native class, and, furthermore, consisted largely of recruits hastily enrolled in an expanded army during the war with Spain. These men, examined largely by civilian physicians for enlistment, were less thoroughly protected against the disease by vaccination; and for that year the admission rate for the entire army was .40 per thousand. For 1898, from the troops in Porto Rico the admissions were 1.04 and the deaths .52 per thousand; in the Pacific islands the admissions were 5.51 and the deaths 2.07. For the entire military force, regulars and volunteers, May, 1898, to June, 1899 inclusive, the death rate from smallpox was .57 per thousand.

Manner of Infection.—In the great majority of cases the disease appears to be directly transmitted from the sick to the well through the medium of the atmosphere, and this power of aërial convection is one of the most striking characteristics of smallpox. Persons unprotected by vaccination apparently contract the disease by simply breathing the air of the space in which a smallpox patient is confined. There is no evidence for or against the transmission of the disease by food or drink or through wounds. Persons or things which may have been in contact with the patient are, however, capable of conveying the contagion. Power showed that the infectious agent could be carried by the air, particularly when a large number of cases were aggregated and the atmosphere was moist, for as much as a mile. This is a matter for consideration in the establishment of isolation hospitals. The incubation period of the disease is practically twelve days, and its period of infectiveness lasts at least six weeks in severe cases. The period of highest infectivity is believed to be during the stage of desquamation, when the morbific agent, whatever be its nature, is dispersed with the fine particles of epidermis that the patient sheds. The disease appears to be contagious at an early stage; after exposure to an infection the susceptible individual should be quarantined for a fortnight. A certain proportion of individuals, according to Notter and Firth about five per cent., appear to be naturally immune to the disease.

Soil and climate appear to have no influence on the occurrence of smallpox. Season appears to affect its prevalence, and in temperate climates the mortality curve is above the mean in the late winter and spring. In the tropics the disease is said to prevail chiefly during the hot season, the rains checking it to a great extent. The negro and colored races are especially susceptible to the disease, and these also suffer a heavy case mortality when vaccination has been imperfectly performed. During the Civil War the admissions among the white troops for variola and varioloid amounted to 5.5 per thousand strength, while the admissions of colored troops for the same cause amounted to 36.6 and the deaths to 12.2.

Prophylaxis.—For the prevention and eradication of smallpox, systematic vaccination is the measure of by far the greatest importance. When arm-to-arm vaccination was practised in armies, great difficulty was found in obtaining the necessary amount of virus, and it was also impossible to eliminate entirely the possibility of transmitting certain constitutional diseases. Animal vaccine disposes of this danger and places at the disposal of the military sanitarian as large quantities as may be desired. With improved virus and better technical methods, the proportion of successful vaccinations has steadily increased. In the Italian army, of 3,095,571 vaccinations and re-vaccinations made during the period 1867–97 inclusive, Livi states that the success increased from 260 per thousand in 1867 to 698 per thousand in 1897. In the last-named year, in the Belgian army, the number of successful primary vaccinations was 69.91 per cent.; of those previously vaccinated, 43.21 per cent.; of those said to have had smallpox, 20.50 per cent. In our service, Army Regulations require that as soon as a recruit joins any rendezvous, regiment, or post he shall be examined by a medical officer to ascertain whether vaccination is required. In such cases as present no evidence of successful vaccination within a reasonable period the operation is to be performed immediately. The date and result of the last vaccination are to be noted in the company descriptive and deposit book, and also on the descriptive list in case of transfer. This system is not sufficiently comprehensive and leaves too much to the discretion of the medical officer. It should be required that all young recruits be vaccinated immediately on enlistment, and that they be examined after ten days and re-vaccinated if the first operation has not been successful. In such as still prove refractory, the operation should be repeated at the end of three months. In time of epidemic the thorough vaccination of the whole command should be practised. For old soldiers, after being vaccinated on re-enlistment, no repetition of the vaccination, if unsuccessful, will ordinarily be necessary. The practice of simultaneously making several points of inoculation, as is done in European armies, has much to commend it as reducing liability to failure. In general, the total area of the cicatrices should not be less than half a square inch. The incubation of vaccinia being shorter than that of smallpox, it is possible to modify or even entirely prevent an attack of the latter, by vaccination performed some days after infection. This is especially the case with re-vaccination, the incubation of which is often shorter than primary vaccination. The operation, if successfully performed within three days after exposure to smallpox, will prevent the appearance of the symptoms, and in all likelihood the attack will be arrested or modified if vaccination be performed as late as the fifth day. The few attacks that occur between six and nine days after successful vaccination are mild, and practically none commence later. With regard to what may be accomplished in controlling smallpox, the recent work of army medical officers in the Philippines, Cuba and Porto Rico is a con-

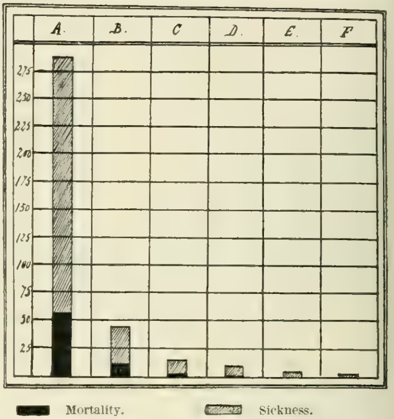

FIG. 1086. The Influence of Vaccination on Smallpox in the Italian Army, Based on Figures for the Period 1867–97. *A*, Never had variola or been vaccinated in childhood and not yet vaccinated in the army; *B*, either had variola or been vaccinated in childhood and not yet vaccinated in the army; *C*, never had variola nor vaccinated in childhood and vaccinated in the army without success; *D*, never had variola nor vaccinated in childhood, and vaccinated in the army with success; *E*, had variola or was vaccinated in childhood, and vaccinated in the army without success; *F*, had variola or was vaccinated in childhood, and vaccinated in the army successfully. (After Livi.)

spicuous example. In the latter island nearly a million people were vaccinated, and the disease was practically eradicated. In the Cuban epidemic at Holguin, where 12,000 cases of the disease were treated, not a single soldier of the well-vaccinated command contracted smallpox, though the men were constantly engaged in sanitary police and in guard duty at the lazarettos and infected points.

In addition to the prompt vaccination of all persons who may have come in contact with a smallpox case, the patient should be carefully isolated. All clothing and other articles exposed to contagion, which cannot be readily disinfected, should be burned. During the stage of desquamation, fixation of the contagious matter should be accomplished by smearing the skin with olive oil, vaseline, or carbolized glycerin. All discharges from the nose, mouth, and elsewhere should be received into vessels containing a disinfectant solution. The scabs which have fallen off should, as far as possible, be collected and burned. Isolation should be maintained until the last scab has disappeared. The surroundings of a case of smallpox should be carefully disinfected. No special precautions on the part of the attendants, provided they are thoroughly protected by vaccination, appear to be necessary.

In nearly all foreign armies, vaccine farms form part of the military establishment. In the French army there are five such farms, of which three are located in France and two in Tunis and Algeria. In our own service admirably managed vaccine stations have been established in Porto Rico and in the Philippines, since it was found to be a matter of both great difficulty and great expense to import active vaccine virus from the United States, Japan, or other countries. In the stations in the Philippines the young water buffalo or carabao has successfully filled the place of the calf for the production of vaccine virus.

Tuberculosis.—*Occurrence.*—Tuberculosis is a disease which originates more frequently in garrison than among troops in active campaign; but, on the other hand, the arduous nature of the service required under the latter conditions is often responsible for the development of a previously latent infection. The disease is not uncommon among troops, a fact by no means strange when its great prevalence among the civil population is considered. It is probably true that a proportionally greater number of cases of tuberculosis occur among soldiers than among males of the military age in civil life, in spite of the former being physically sound men; but, on the other hand, the disease is of a somewhat chronic nature, not usually amenable to such treatment as can be given in the military service, and hence the early discharge of well-recognized cases does much to depress the rates for the army and raise those for civil life. Military service appears not only to afford greater facilities for contracting the disease, but also to more certainly develop an existing but latent infection.

The mortality from tuberculosis was extremely high among troops at the beginning of the present century, but has gradually decreased down to the present time as a result of more attention to their welfare. In our own service the admission rates for tuberculosis, during the Civil War, amounted to 6.22 per thousand strength; the death rate to 2.53. During the second year of the war the admission rate was 9.38 and the death rate 3.05. For the period of peace, 1868–84, the admissions amounted to 4.88 per thousand strength, and the deaths to 1.05. For the decade 1885–94 these rates fell to 3.39 and .59 respectively; and for the period 1895–98 they were still further reduced to 2.83 and .42. These rates are low as compared with those for other armies, and reflect credit upon the care given to our troops; but their existence, even at present figures, implies a certain laxity of sanitary administration. The death rate from this cause should be made to approximate zero through a more prompt and thorough elimination of those affected with tuberculosis, while a higher physical standard in respect to recruits would do much to reduce the future admissions to sick report from this disease. At present our rates are considerably raised by the military sanitarium for the tuberculous maintained at Fort Bayard. In foreign armies, figures with respect to the occurrence of tuberculosis, as given by Marvaud and contained in recent official reports, are as follows:

Country.	Period.	Admissions per 1,000 strength.
Germany	1873–79	4.3
	1881–91	5.7
	1891–97	2.57
Austria	1878–81	4.2
	1889–91	4.7
	1893–97	1.76
England	1870–83	6.1
	1885–90	3.5
	1888–97	3.7
Russia	1890–97	4.2
Italy	1875–81	3.16
	1882–91	3.82
Spain	1886–91	7.75

In the Russian and French armies the death rates are particularly high, being 1.6 and 1.10, respectively. The lowest death rate is given by the Belgian army, in which, as a result of careful elimination of the tuberculous, the rate was but .35 per thousand strength in 1898. For the year 1897 the death rate was .45 in the German army. Among the British troops on colonial service, during the decade 1888–97, the lowest rates of admission were given by Gibraltar, 1.9, and Bermuda, 2.4. The highest rates were given by the troops in India, 4.2, and in Ceylon, 4.1. For the Spanish army in Cuba, in 1897, the admission rate for tuberculosis was reported to be in excess of that for yellow fever, dysentery, or typhoid fever.

Dissemination and Infection.—Every tuberculous soldier is a source from which the disease may be propagated to his comrades. The particular manner in which the infectious material is thrown off depends upon the anatomical location of the tuberculous lesions. Undoubtedly the disease is most commonly disseminated by infected sputum, but this is merely because the specific bacilli more commonly find in the respiratory apparatus the conditions which are favorable to their development. It should not be overlooked that under certain conditions the urine, fæces, or discharges from superficial lesions may be proportionally as infectious as the sputum.

In the sputum of those affected with pulmonary tuberculosis the specific bacilli are usually found in enormous numbers. When such infected sputum is dried, pulverized, and disseminated as dust by air currents, the infectious material may be inhaled by those within its sphere of action, and, in susceptible individuals, may reproduce the disease. The same may also occur with tuberculous urine, fæces, and suppurative discharges. In the dried state the vitality of the bacillus is very great, and it has been shown to retain its virulence under these conditions for as long as from seven to ten months. In the wet state, its virulence is retained for about six weeks; but in this condition it is comparatively harmless, though not entirely so. Cornet found that the dust in rooms occupied by consumptives contained virulent tubercle bacilli in a large proportion of cases. Such dust, disturbed from cornices or out-of-the-way places, even after several months, is often capable of producing an infection, and to its agency the appearance of many cases of obscure origin may be attributed. In a study of consumption occurring in Philadelphia it was found that certain infected tenement houses were apparently responsible for a large proportion of cases; in some instances every family successively occupying these houses presenting one or more cases of the disease after an occupancy of any duration. These observations have a practical application to the military service in connection with the disinfection of barracks in which a case of this disease has occurred.

While the breath in consumptives does not appear to convey the infection, fresh tuberculous material, after infection, may be transmitted to food or drink by unwashed hands or other agency, and give rise to the disease when taken into the alimentary tract. Vigoura, in ten examinations of the hands of hospital attendants in wards where consumption was being treated, found the tubercle bacilli present in two instances. In the same way, infected individuals who cough over food may also disseminate the affection. Flies feed greedily on tuberculous material, and their importance as carriers of the specific bacilli has only recently been appreciated. Much evidence on this point has lately been collected. Spillman and Haushalter examined the flies and fly excreta in a hospital ward and found tubercle bacilli in both. Hoffman examined the intestinal contents of flies taken from a room where a death from phthisis had recently occurred and found the bacilli in four out of six instances, as well as in the fly excreta on the walls and furniture. Guinea-pigs inoculated by him with fly intestine became tuberculous. Alessi fed flies with phthisical sputum and produced tuberculosis in rabbits inoculated with their dung. It is thus apparent that food may be readily contaminated by flies carrying infectious material. Tuberculous meat may also be a cause of the disease; and in civil life milk from diseased animals is not infrequently infected. Clothing or other articles, when infected, may convey the disease to those persons who handle them, and in such instances the disease appears to result from infection by way of the alimentary tract. Inoculation through a breach of the skin has often occurred, but such method of infection is not common in the military service. When it does occur, the process is usually localized at the site of infection. Direct infection from the sick is rare, but there appears to be evidence to the effect that the disease may be communicated by the sick to the well. In instances of this sort, however, the affected individuals can scarcely be said to have been free from the possibility of infection by indirect means also.

Predisposing Causes.—The disease occurs in all countries and climates, but is especially prevalent where sudden changes of temperature and damp atmosphere favor the occurrence of bronchial irritation, the tuberculous element being thus engrafted upon a simple benign affection. A dry, equable, sunny climate does much to prevent the occurrence of this disease, and the same may be said with respect to altitude. Of the greatest importance in determining the occurrence of this disease is the so-called tuberculous diathesis. There seems to be no doubt that certain individuals present a hereditary susceptibility to this disease, and this predisposition may generally be recognized by the well-known physical signs. Among these chest capacity is important, and it is of interest to know that, in the German army, where the chest of a soldier does not properly develop under physical training, the man is regarded as predisposed to phthisis and returned to civil life.

Race exerts a considerable influence on the occurrence of tuberculosis, though no race is exempt. The negro and Indian are especially predisposed to this disease. Among the Apache Indian prisoners removed from Arizona to Alabama a few years since, the annual death rates per thousand, for five years, were 55, 51, 110, 146, 110—almost wholly from tuberculosis. For the white race, nativity seems to be not without influence in modifying susceptibility. In the United States army, for the seven years 1890–96, the admission rates for tuberculosis, per thousand strength, were 3.33 for American whites, 2.97 for soldiers born in Ireland, and but 1.49 for those of German birth. In the examination of 501,068 recruits, during the Civil War, Baxter states that rejections for tuberculosis were more frequent in blonds than in men of dark complexion; and that the proportion of rejections increased directly with the height. Age is a factor of great importance in the occurrence of the disease. For the period 1890–96 the admissions for tuberculosis in our army, per thousand of each class, were proportioned as follows:

Period.	Admissions.
19 years and under	5.03
20 to 24	3.44
25 to 29	3.09
30 to 34	2.69
35 to 39	2.70
40 to 44	1.87

The rates for infantry are slightly higher than for cavalry and artillery, and nearly three times as high as those for the Medical Department; the latter showing the beneficent effect of lessened exposure and overcrowding. For the period 1890–96 the admissions were about two-thirds as frequent among officers, 1.98, as among enlisted men, 2.96.

Nothing is better established with regard to tuberculosis than its relation to overcrowding and bad ventilation. As long ago as 1858 it was shown in the British army that the troops which suffered the most from overcrowding presented the greatest amount of tuberculosis. The custom of living in common, as in barracks, greatly favors the occurrence of tuberculosis, since where an infection of the building has occurred all the occupants are equally exposed to the danger of contracting the disease. Casemates, from their dampness, defective ventilation, and want of sunshine, particularly favor the occurrence of tuberculosis among troops quartered in them. No more striking example of the influence of habitations on the frequency of tuberculosis has been given than that reported by Davy, in 1862, as witnessed by him at Fort Clarence, in England. At this post, converted into a military lunatic asylum, the deaths from tuberculosis among officers and among soldiers' wives, these being lodged in ordinary houses, furnished 19 and 18 per cent. respectively of the mortality from all causes. Among the soldiers quartered in casemates, tuberculosis caused 39 per cent. of all deaths. A susceptibility to tuberculosis may be acquired by individuals, ordinarily resistant to the disease, through insufficient and improper food, want of exercise, poor ventilation, and uncleanliness of the person and surroundings. As in other diseases, any circumstance which tends to lower the powers of vital resistance favors infection.

Prophylaxis.—In the military service the prevention of tuberculosis depends largely upon the careful selection of recruits and the avoidance of enlisting such as appear to have a predisposition to this disease. If such have been enlisted, they should be discharged. All soldiers affected with the disease should be promptly discharged from the service, as their retention is a menace to others.

Among other measures of prevention may be mentioned the location of barracks on dry, elevated, sunny sites; the provision of sufficient cubic space, and thorough ventilation; the avoidance of sharp corners or projecting ledges upon which dust can collect, and the rendering of floors impermeable with paraffin. Spitting on the floor and walls, aside from its being an offence against neatness and decency, should be prohibited for sanitary reasons. Metallic spittoons of a pattern readily cleansed should be provided, and should contain a small quantity of some odorless disinfectant solution so as to keep the sputum in a moist condition. These receptacles should be cleansed and scalded daily. Box spittoons containing sawdust, as too often found, should never be employed. They are not only a danger to health, but are often ignited by cigar and cigarette stubs. It should not be forgotten that a squad room which has contained a case of tuberculosis is not safe for occupancy until disinfected. In the routine cleaning of barrack rooms the use of dusters should be avoided, and all dust should be removed from shelves and projecting ledges by means of damp cloths. Meat from tuberculous animals should be rejected for issue. An abundant diet containing a considerable amount of fat appears to be of value in the prevention as well as treatment of this disease. Chilling and exposure, which favor bronchitis and pleurisy, predispose to tuberculosis and should be avoided. Exercise in the open air, especially such exercise as increases the mobility and capacity of the chest, is desirable.

With reference to the measures to be applied to the affected individual, the disinfection of the sputum and other discharges from persons suffering from various manifestations of the disease is of the most importance. The patient should be impressed with the fact that he is a possible source of infection, and that it is quite within his power to control the spread of the disease to others by attention to a few simple details that in no way interfere with his comfort. Special spit-cups should always be provided for the sick; since otherwise while endeavoring to use those on the floor they will frequently cause its contamination. When the spit-cups cannot be used, clean rags or rice-paper napkins may be employed, and these subsequently destroyed by fire. Bed or body clothing, soiled with tuberculous material, should be at once removed and disinfected. The bedding of the tuberculous should never be used by the well. All blankets should be frequently sunned, and great care taken to prevent their being shaken under circumstances which would allow the dust to be inhaled, or become a means of infection to others. The tuberculous individual should be provided with separate eating utensils, and these disinfected after use. The uneaten portions of food should be burned. All personal contact between the sick and the well is to be avoided.

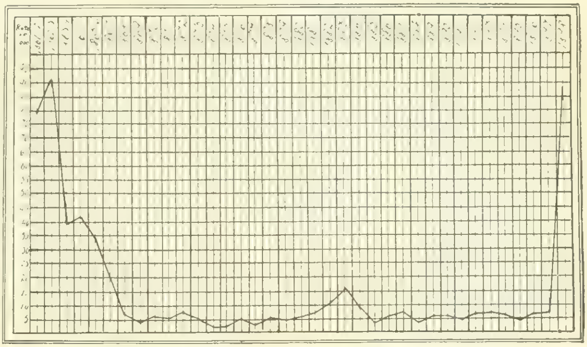

FIG. 1087.—Admissions for Typhoid and "Typho-Malarial" Fevers, per Thousand Strength, Occurring in the United States Army During the Period 1861–98, Excluding the Year 1867.

Typhoid Fever.—*Occurrence.*—The history of typhoid fever, as a disease of soldiers, scarcely extends over a period of fifty years, it being previously confused with several other affections. About half a century ago the disease was differentiated from typhus fever by Murchison, both previously being classed together by medical officers as "spotted fever"; and undoubtedly much of the fatality which prior to this time had been regarded as due to typhus was in reality due to typhoid infection. In addition, no distinction was long made between enteric fever and the continued malarial fevers. Shortly before and during the Civil War, however, medical officers were forced to recognize the different characteristics of typical cases of these diseases, and about the same time the term "typho-malarial" was adopted to cover that class of cases which, while they presented some of the clinical symptoms of both diseases, were apparently identical with neither. Later, the fact that most of these cases of typho-malarial fever were in reality typhoid infections was strongly suspected; but it was not until Laveran, of the French army, discovered the malarial parasite that the differentiation between enteric and malarial fevers was definitely made. In the French army the official recognition of the existence of a disease intermediate between malaria and typhoid was withdrawn in 1888, and about the same time the term typho-malarial was discontinued in our own medical nomenclature. This example has since been followed in all the more important armies, and military statistics for this disease, for the past ten years, may be regarded as much more accurate. In the Russian army, however, even as late as 1897, no small proportion of the continued fevers were classed as "undetermined" in nature. It is obvious, therefore, from the difficulty which has until recently existed in the recognition of typhoid fever, that statistics for the periods prior to the past decade are of little value for purposes of comparison between different armies, and even for the same service they are not free from error. For our own army it may safely be assumed, from a better knowledge of the nature of the typhoid infection, that cases which have been recorded as typho-malarial are in reality largely cases of enteric fever.

Typhoid fever at the present time is the most important disease affecting soldiers. While it prevails to some extent among troops in garrison, it is among soldiers in the field, and especially those in camps of more or less permanency, that it makes its greatest ravages. In this country, as in all temperate or tropical regions, enteric fever is so prevalent and its specific cause so widely disseminated that no camp of any size or permanency can be expected to remain free from its infection. In the camps of our army during the war with Spain not a single regiment escaped its ravages. According to the board appointed to investigate the epidemics of typhoid fever during this war, nearly all the regular troops and ninety per cent. of the volunteer regiments developed typhoid fever within eight weeks after going into camp; in the northern equally as much as in the southern parts of the country. This condition, far from being unusual, is what has commonly prevailed among all troops in active service; and Davies particularly notes a number of instances of epidemics occurring early in successive British military expeditions. The recent Anglo-Boer War in South Africa was no exception to this rule. It has been repeatedly observed, especially in the camps of 1898, that while troops in camp are heavily scourged, the surrounding civil population may remain wholly unaffected. The conclusion is inevitable that conditions ordinarily found in military encampments or governing troops in the field are extremely favorable to the propagation of this disease; and this fact is abundantly demonstrated by figures for our own service. During the Civil War period, 1861–66, the admissions for typhoid and typho-malarial fever amounted to 57.71 per thousand strength, while for the sixteen years following the war, 1868–84, the admissions for the same cause were only 6.29 per thousand strength. Again, in 1898, during the war with Spain, the admissions for typhoid fever amounted to 88.55 per thousand strength; during the year 1897 they amounted to 6.25, and during the decade 1885–94 they were only 5.51 per thousand strength. Throughout the period of peace, 1868–97, the rates for typhoid fever showed no very great variation except for the years 1882 and 1883, when sharp localized outbreaks of the disease occurred, and for the years 1874 and 1875, when the rates fell much below the normal. Of late years the disease has shown a tendency to become slightly more prevalent among our troops, in spite of the much improved sanitary conditions under which the soldier now lives. It is possible that the reduction in the period of enlistment from five to three years, through the greater proportion of more susceptible material in the army which is thus maintained, has had an effect in neutralizing sanitary improvements as far as their influence on enteric fever has been concerned. The relative prevalence of typhoid fever in our army, since the year 1860, together with the remarkable increase induced by camp life, is shown by the accompanying diagram (see Fig. 1087).

During time of peace the mortality from typhoid is not high in our army as compared with the country at large. For the year 1896 the death rate was .48 per thousand; this being lower than the typhoid mortality rates in most of our large cities, such as Washington, Chicago, Pittsburg and Philadelphia, notwithstanding the great susceptibility of men of the military age to this disease. In the French army, however, Coustan states that the relative amount of sickness due to typhoid fever is constantly five or six times greater than among the civilian population. During time of peace there has been no great epidemic of this disease in our army, the highest rates of admission being given in the years 1882 and 1883, when the admissions per thousand, for the entire army, amounted to 11.23 and 15.06, respectively. The rates are undoubtedly kept low through the fact that our troops have in the past been scattered in small commands over a large area, and that an infection of an individual water supply was therefore not able to affect a large number of troops at once, as is often the case in foreign armies. A considerable proportion of those exposed to the infection have at times contracted the disease. Viry and Coustan cite epidemics in the French army, in 1875, in which 10 per cent. of those exposed contracted the disease at Nanly, 18 per cent. of those at Saratory, and 25 per cent. at Brest. In 1889, of the troops at Dinan, 60 per cent. of the command contracted typhoid during a single epidemic. The board which investigated this disease during the war with Spain concluded that not less than one-fifth of all the troops located at the camps of mobilization were affected with typhoid fever, either in recognized or in unrecognized forms. It also stated that in all probability the deaths due to typhoid fever amounted to more than 80 per cent. of the mortality from all causes.

With regard to the occurrence of typhoid fever in foreign armies, Coustan gives the rate in the French army as follows:

Period.	Admissions per 1,000 strength.	Deaths per 1,000 strength.
Before 1888	From 12 to 31	2.5
1888	13.2	1.7
1889	11.6	1.6
1890	10.5	1.71
1891	10.77	1.95
1892	12.12	1.54
1893	9.59	

Before 1888, typhoid fevers and continued fevers were classed together. Up to 1893, typhoid was the cause of about one-third of all the deaths occurring in the French army. Marvaud gives the case mortality for the period 1878–90 as about sixteen per cent.

In the German army reports the rates of admission and death for typhoid fever, per thousand strength, are given as follows:

Period.	Admissions per 1,000 strength.	Deaths per 1,000 strength.
1881–82 to 1885–86	5.6	0.46
1886–87 to 1890–91	3.6	.28
1891–92 to 1895–96	2	.21
Year 1895–96	1.7	.19
Year 1896–97	1.3	.16

The small proportion of cases of this disease, together with the reduction which has steadily gone on, shows most forcibly the admirable sanitary condition of the German army.

In the Russian and Austrian armies the admission rates have of late years been as follows:

Year.	Russian army per 1,000 strength.	Austrian army per 1,000 strength.
1890	9.6	
1891	7.9	
1892	7.6	5.7
1893	7.2	14.0
1894	6.7	3.7
1895	7.7	3.1
1896	7.9	3.5
1897	8.4	3.8

In 1897 the death rate for the Russian army was 1.37.

The admission rates for the British army, at home and on foreign service, are given elsewhere in this section. In the Spanish army, according to Coustan, the admission rate for the year 1886 was twelve per thousand.

For the Italian army the mortality from typhoid has recently been as follows:

Year.	Deaths per 1,000 strength.
1893	1.12
1894	.84
1895	1.15
1896	1.10
1897	.98

In the Belgian army, for 1898, the death rate from typhoid was .28 per thousand strength.

Elimination of Infectious Material by the Sick.—It has long been recognized that the fæcal discharges of typhoid patients contain the specific bacillus and are a potent factor in the dissemination of the disease. The enteric bacilli are not usually found in the stools earlier than the seventh day, although the latter are probably infective during the incubation period and certainly during the onset of the disease—and they ordinarily disappear soon after convalescence is established. In some cases, however, the bacilli have been found as late as forty-one days after defervescence. The stools appear to gain in infectivity for several days after discharge from the sick person, but the reasons for the increase in virulence are not as yet understood.

The elimination of typhoid bacilli by the kidneys affords a ready means of spread which has not sufficiently engaged the attention of medical officers; and in investigating the cause of typhoid fever in military camps this mode of dissemination is too often overlooked. Enormous numbers of the bacilli are frequently, though apparently not invariably, present in the urine. When they do occur, it is late in the disease and during convalescence. In 38 cases, Richardson found the bacilli present in 9; always in large numbers and practically in pure cultures. They appeared only in the later stages of the disease and persisted far into convalescence. Smith found them present in 3 out of 7 cases examined by him, and observed that they may be present in sufficient numbers to render the urine turbid. Petruschky found typhoid bacilli in urine two months after the temperature had become normal, and calculated that in one instance the urine contained 170,000,000 typhoid germs in each cubic centimetre. In many cases the urine in convalescence has been found to be swarming with typhoid bacilli, while none could be detected in the fæces. In certain instances this condition has been found to persist for years. Richardson has reported an old case of cystitis in which the bacillus was found in pure culture in the urine five years after the attack; and similar results have been obtained by Houston and others. Horton-Smith finds that the specific bacilli are present in the urine in one-fourth of the cases of the disease, and, when present, occur in far greater quantity than in the fæces. In comparing the two as to the most dangerous and frequent cause of the disease, he concludes that this is "the urine, and this partly on account of the enormous numbers of bacilli which may occur in it, and partly on account of the excretion itself. Thus the stools by their color and odor at once attract attention, so that the slightest soiling of the linen is at once noticed and the damage rectified; but the same cannot be said of the urine." It can readily be seen how a convalescent from typhoid fever, prematurely returned to duty, may infect the soil of his company camp by urine surreptitiously passed at night; where such contamination by fæcal matter would be scarcely possible, and if it occurred would be readily detected and measures promptly taken to limit its evil effects.

It has recently been questioned whether the sputum in typhoid fever may not be infectious. Investigation on this point by Williams and others has given positive results in a number of instances. How early the bacilli may appear and how long they may persist are matters which have not as yet been determined.

Methods of Dissemination among Troops.—The typhoid bacillus undoubtedly obtains entrance into the system by being swallowed either with the water or with the food, or by drawing into the mouth or pharynx the germs suspended in the air, or by placing in it some specifically contaminated object.

In the epidemics of towns or large garrisons, water usually serves as the vehicle for the infective agent; but in military camps there are many modes of infection, and in the typhoid epidemics of 1898 contaminated water was one of the least important factors. Vaughan says: "There probably were local water supplies that became specifically infected with the typhoid-fever bacillus, but infected water was not the great factor in the causation of this disease," and this opinion will be shared by those who had experience in field service during the period named. At Jacksonville, Lexington, and Knoxville, the troops used the same water supply as the adjacent civil population, yet one class had typhoid and the other had not. At Jacksonville there were only a few sporadic cases in the city, while in the adjoining camp, with about the same population, the admissions to hospital for typhoid fever were 60 or 70 per day. In Knoxville not a case occurred among the citizens at a time when there were hundreds of cases among the soldiers. In time of peace, however, the part played by drinking-water in the occurrence of typhoid is very great. Instances might be multipled indefinitely to prove this point, and among these instances perhaps the best examples have occurred in the military service, and particularly in the French army. For the year 1886, among the French troops, the number of cases of typhoid fever amounted to somewhat over 14 per thousand strength. In 1894 it had been reduced to slightly less than 6 per thousand strength; the result being obtained by an almost progressive yearly decrease. In 1895 the Minister of War reported that in 29 garrisons formerly extremely subject to typhoid fever, in each of which an uncontaminated supply of drinking-water had been provided, there had followed an almost total disappearance of this disease, and the few isolated cases which occurred were shown to have originated outside the barracks. In those cases in which a new water supply had been provided and the water was drunk unfiltered, epidemics followed from time to time on the contamination of the source and disappeared after the introduction of Pasteur filters. At Avesnes, after the installation of these filters, 105 cases in 1891 became, for the next three years, only 1 annually. At Auxerre, 129 cases in 1892 were reduced to 1 each in 1893 and 1894. At Melun, 122 cases in 1889 fell to 7.4 for the following five years. At this last post, in February, 1895, 28 dragoons were suddenly attacked, the infantry battalion in the same barracks having not a case. Investigation showed that the Pasteur filters had been allowed to freeze, and the soldiers had been ordered to drink only the weak infusion of tea, in which the water had been boiled, furnished them. While the infantry had obeyed, the dragoons had not, and had helped themselves to the Seine water from the hydrants. At Cherbourg, with a previous annual average of 114.5 cases, the installation of Pasteur filters in 1890 reduced the cases to 28, 8, 11, 3, and 3 in the succeeding five years. At Dinan, with a previous annual average of 278 cases, the installation of Pasteur filters in 1890 reduced the number of cases to 1, 2, 3, and 1 respectively during the next four years. At Lorient, until 1889, there was a yearly average of 170 cases of typhoid fever among the garrison. In 1890 filters were set up, with the result of a decrease to 58 in that year, while the three following years numbered 2, 1, and 1 respectively. In 1894 water was brought into the barracks at this station from a spring supposed to be pure, and 11 cases of typhoid shortly appeared. On examination the water was found to be contaminated, and the disease practically ceased to exist among the garrison upon its disuse. Viry states that of 194 epidemics of typhoid fever occurring in garrisons of the French army during the period January 1st, 1887, to January 1st, 1890, no less than 187 of them could be directly associated with a "defective, doubtful, mediocre, or infected water supply." Many instances of the relation of typhoid fever to drinking-water of bad quality have occurred in our own army. At Jefferson Barracks the typhoid which prevailed endemically at that station diminished greatly when a purer supply was substituted.

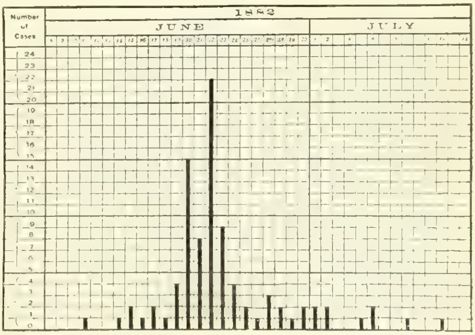

FIG. 1088.—Course of Typical Water-Borne Epidemic of Typhoid Fever, Occurring in the Garrison at Wittenberg, Germany. (After Gaffky.)

Except in rare instances, examination of a water supply during an epidemic of typhoid has failed to reveal the specific germ of this disease. It has, however, usually determined the presence of the bacillus coli communis, showing the probability of infection with typhoid discharges. In character, an epidemic of typhoid due to an infected water supply will be marked by the suddenness of the outbreak and the simultaneous occurrence of a large number of cases. The accompanying diagram (Fig. 1088) typically illustrates the course of a water-borne epidemic. As in most places the water supply soon regains its purity, no increase subsequently may be anticipated unless a second infection of the water supply occurs. In typhoid spread by other means than water, as in camp epidemics, the onset of the epidemic is gradual. With each case additional sources of infection are developed, and the prevalence of the disease steadily increases as long as efficient preventive measures are not taken and there is an abundance of susceptible material.

Among articles of food, milk is not infrequently contaminated with typhoid germs from infected water which may have been added to it or used to wash the dairy utensils. Many other articles of food which are eaten uncooked are liable to spread the disease, especially vegetables. Recently an epidemic of typhoid fever occurred in the Insane Asylum at Northampton, Mass., resulting from the use of celery watered with filtered sewage. Among many similar cases one was lately reported by Ferre in which an epidemic in a school followed the use of vegetables watered with the contents of a cesspool which received the evacuations of the pupils. Watercresses grown in ditches contaminated by sewage have been known to serve as the vehicle for the infectious agent. In 1895 Deshon reported several cases of typhoid, occurring at a western station, which he believed could be traced to the use of heavy, sour and indigestible bread.

Among troops in camp during warm weather the use of food contaminated with the typhoid bacillus, brought from the latrines by means of flies, to whose feet the germs readily adhere, is a factor of the greatest importance in spreading the disease. Numerous observers have detected the specific bacillus in the excrement of flies made to feed on infected material, and colonies of typhoid bacilli have been shown to develop in the tracks of these insects which had been allowed to settle on typhoid discharges and then made to walk over a suitable solid culture medium. Vaughan states that, during 1898, in some of the large military camps where lime had recently been sprinkled over the contents of the latrines, flies with their feet whitened with this substance were seen walking over the food. He also noted that officers whose mess tents were protected by means of screens suffered proportionally less from typhoid fever than did those whose tents were not so protected. When flies are numerous in camp and are constantly settling upon and contaminating all articles in common use, it is easy to see that even if the food and drink be protected from their invasion, an infection may readily be brought about by touching the lips with the fingers or other articles upon which the typhoid bacilli have been deposited. The typhoid epidemics of 1898 gradually decreased with the approach of cold weather and the disabling of the fly as a carrier of the infection. It is well to remember that when a strong wind constantly blows from the same direction, a fly-borne epidemic will extend chiefly down wind, as this insect always rises, and generally moves, in the direction of air currents. Flies lay their eggs in nearly all organic material, especially if this be in a putrid condition. Howard regards horse manure as the most favorable breeding material, but in the camps of 1898 the larvæ were often seen by thousands in illy-policed latrines. Sprinkling the latrines with earth, as ordinarily practised, did not appear to destroy them. Care with respect to preventing organic contamination of the camp space and in carrying out proper measures of latrine disinfection will do much to prevent their development. The life of the fly is short, but the cycle of development is rapid. According to Howard, under favorable conditions the egg hatches in eight hours, the larvæ pass to the pupal state in from sixty hours to three days, while from pupation to the issuing of the adult requires about five days. As the life cycle is complete in about ten days and the individual insect lays about one hundred and twenty eggs at a time, the enormous numbers in which these insects may occur in standing camps are readily accounted for.

Typhoid fever may also be transmitted by aerial infection from drains, water-closets, latrines, dust heaps, urine or fæcal discharges which have been allowed to dry on the linen or person or in receptacles. In this condition the bacilli are capable of being carried considerable distances through the air to settle down on water, clothing, or food. It is not yet determined whether the disease can be contracted by breathing air containing suspended bacilli, but certainly in the case of mouth-breathers they should readily find their way to the pharynx and thence be washed into the alimentary canal by the act of deglutition. It is true that complete desiccation soon destroys the typhoid germ, but in practice it is not always completely desiccated, and Flügge and Fischer have shown that the enteric bacillus can successfully resist for a time a considerable amount of drying. Allchin, moreover, states that but a comparatively slight current of air, 4 metres per second, is sufficient to raise germs into the atmosphere from the surface of liquids or wet ground. The dissemination of typhoid by means of dust was undoubtedly a potent factor in its spread, in 1898, in the camps at Jacksonville and Tampa. In this connection it is interesting to note that, in 1885, the British troops at certain stations in the Soudan used only distilled water, yet typhoid was very prevalent. No reason for the spread of the infection could be shown except that the excreta were dried, converted into dust, and scattered over the camp by the desert winds. In the French army, Nollet was recently able to determine the presence of the typhoid bacillus in the dust of cracks in the barracks at Cherbourg, in which garrison typhoid had prevailed epidemically.

Personal contact also does much to spread the infection, especially among raw troops. Where lack of discipline permits the pollution of the ground in the vicinity of the camps by the indiscriminate deposition of human excreta, a certain proportion of such discharges will assuredly be infected and portions may be carried into camp and tents on the shoes of incautious passers. Uncleanly seats in latrines, or the ground therein, may specifically contaminate the person, hands and clothing of those resorting to them. Where troops are detailed to do the heavier labor about hospitals, as is often the case during epidemics, the opportunity for an infection to be carried back into camp through their agency is often great. The board which investigated the occurrence of typhoid fever in 1898 was struck with the fact that men who were closely associated in the same company or tent almost simultaneously developed typhoid fever, apparently through a localized infection imparted from the same sources.

Heavy rains do much to disseminate typhoid among encamped troops, especially where there is bad sanitary police. Where sinks are dug in impervious soil and are so located as to receive surface drainage, they may be overflowed by storm waters and distribute their contents over the adjoining surface—to be later dried by the sun and scattered as dust by the feet of men and animals and the wheels of passing wagons. During the war with Spain, in camps where the tub system for the reception of excreta was in use, careless handling and transportation by the scavengers resulted in the scattering of fæcal matter, much of which was infected, almost broadcast over the camp area.

A fruitful cause of the dissemination of typhoid throughout a camp lies in the fact that no small proportion of soldiers, with mild infections or with ambulant cases of typhoid, either do not go on sick report until the typhoid condition is well advanced, or not at all. In many cases, also, the nature of the comparatively slight prodromal symptoms presented are not recognized by the medical officer, and the case for a considerable period is treated in quarters as one of diarrhœa or similar trifling affection. This is particularly true in cases, noted by Allchin and others as being not infrequent, in which the individual has been exposed to great hardships, and in which the temperature is normal or sub-normal throughout the attack. As already stated, the stools in typhoid fever are probably infective even during the period of incubation, and there are probably a considerable proportion of cases in which an infection does not develop the typical disease, through either an attenuation in virulence of the specific germ or more or less marked insusceptibility on the part of the subject. The experience of French medical officers in Algiers and Tunis would seem to show that apparently healthy persons may long carry the germs of typhoid, which, later scattered under favorable circumstances, develop the disease in others. British medical officers have noted the same in India and elsewhere—particularly during the Afghanistan expedition. Many instances have been recorded also in our own service, especially in the days of Indian warfare, where outbreaks of the disease occurred among troops who had been for weeks in regions that were not known to have ever before been penetrated by man. From these facts army medical officers in all services have, in the past, favored a theory of the *de novo* origination of typhoid, or of the metamorphosis of the specific germ from the colon bacillus under suitable conditions. It is easy to understand, however, in the light of recent investigations as to the infectiveness of typhoid urine, how the microbe of this disease can be carried with troops for long periods without its presence being suspected, and then give rise to an epidemic when favorable conditions are encountered. Since the period of incubation is twelve or fourteen days—or even in some cases as long as twenty-three days—it is obvious that infected individuals may be passed as healthy and sent to other stations, there to develop the characteristic symptoms of the disease and to serve as the starting-point for new epidemics. This was repeatedly shown to have occurred among recruits sent out from Jefferson Barracks—formerly endemically affected with typhoid fever—to western stations. Further, convalescents from typhoid, returned to duty at too early a date, may be unrecognized but potent agents in the origination of the disease in others. All these classes of cases are particularly a menace to the health of a command under canvas, since by their agency every latrine in the camp may become infected, and the probability of contamination of the camp space, and perhaps tentage, by infected urine and saliva is so great as to approach certainty.

Direct contagion from the obviously diseased to the healthy plays a strong part in the spread of enteric fever. There is no reason for positive belief that the poison is given off in the breath or the emanations from the body, but it is probably contained only in the urine, the fæces and, to some extent, the saliva. If these be properly disinfected and disposed of, if strict cleanliness be observed, and if attention be paid to the disinfection of the soiled linen, the risk of contagion may be reduced to a minimum. Nevertheless, it has not been found possible with all precautions entirely to prevent the spread of the disease to the attendants. During the typhoid epidemics of 1898 the admissions for this disease from the Medical Department and Hospital Corps amounted to 193.41 per thousand strength, when the rate for the army as a whole was 88.56. This fact specifically demonstrates the immediately transmissible character of the affection.

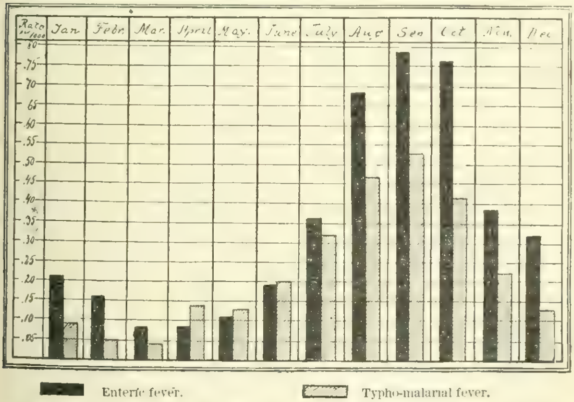

FIG. 1089.—Chart Showing the Distribution by Months, per Thousand Strength, of Cases Diagnosed as Enteric and Typho-Malarial Fever, Occurring in the United States Army During the Decade 1875–84.

Causes Predisposing to Typhoid among Troops.—Typhoid fever occurs in all climates, outside the polar regions, but increases in prevalence as the equator is approached. In the British army, distributed as it is all over the world, the prevalence of typhoid varies greatly. For the year 1898 and the decade 1888–97, the rates per thousand of English troops at different stations were as follows:

Station.	Year 1898.			Decade 1888–97.		
	Admissions.	Deaths.	Constantly sick.	Admissions.	Deaths.	Constantly sick.
United Kingdom	1.9	0.22	0.31	1.2	0.24	0.20
Gibraltar	4.2	1.32	.74	5.4	.95	1.05
Malta	21.2	6.38	2.44	6.6	2.48	1.15
Egypt and Cyprus	81.0	23.40	11.12	21.3	4.37	3.90
Canada	....	...	.	1.3	.21	.25
Bermuda	15.0	2.31	2.56	34.8	6.28	5.13
West Indies	1.1	.55	.23	9.0	2.15	1.36
South Africa	32.9	55.77	4.88	12.8	1.87	1.93
Mauritius	14.6	4.86	2.37	15.0	5.34	2.15
Ceylon	2.1	1.43	.09	6.9	2.13	.84
China	1.9	.64	.39	1.5	.50	.21
Straits Settlement	.7	.71	.17	1.9	.88	.29
India	36.3	10.04	4.90	21.8	5.75	3.12

On averaging together the figures for the two cold stations, the United Kingdom and Canada, for the decade 1888–97, the admissions per thousand strength are seen to be 1.25, the deaths .22, and the constantly sick .22. For the same period the average rates for the remaining stations, located in hot climates or in the tropics, were: admissions, 12.4; deaths, 2.97; constantly sick, 1.92. From these figures it appears that British soldiers in hot climates or in the tropics are almost exactly ten times as liable to contract the disease as those serving in cool climates; while the liability to death from this disease is fourteen times greater. The apparently shorter course run by typhoid in the tropics, as expressed by the rates for constant sickness, is merely due to the higher rate of mortality, by which the elevation of the former figures, through tardy convalescence, is prevented. In our own service, for the year 1898, the admissions for this disease per thousand troops stationed in the tropical islands were 102.18 and the deaths 13.88; while of troops within the United States during the same period the admission rate was 85.46 and the death rate was 8.79. It should be remembered, however, that troops were exposed to tropical influences but a small part of that year, and that for full periods of service the difference in rates would undoubtedly have been much greater. Within the limits of the United States the influence of locality is marked. The amount of typhoid fever in the Department of Texas is almost twice as high as in any other military department. In 1890 it was more than six times as high as in the departments of the East, California, and Arizona. In 1897 it was fourteen times as high as in California, and much higher than in the other departments. Coustan states that typhoid fever is far more prevalent in Algiers and Tunis than in France.

As to season, the disease prevails especially in our army during the late summer and early autumn. For the decade 1875–84, as shown by the accompanying diagram, the disease occurred least frequently during March and April and prevailed most extensively in August and September. In the French and German armies it prevails to the greatest extent during and after the manœuvres in August and September; in the Austrian army its prevalence is greater during the July manœuvres. Certain notable outbreaks have occurred in the spring, but these are invariably to be traced to a localized water-borne infection and are exceptions to the general rule.

Military experience shows that an infection of enteric fever often fixes persistently upon a single barracks, post, or district. As a rule, in those localities in which the disease is endemic, it will be found that unsanitary conditions abound; notably impure water supply, defective methods and arrangements for the disposal of excreta, and want of care in respect to preventive measures. In India, typhoid fever has been found to be a more difficult disease to eradicate from military posts than cholera, persisting with great tenacity and recurring year after year in spite of all efforts—and it has even been found necessary to abandon stations for this reason. Within these endemically infected areas newcomers are especially liable to attack, those long resident in such a zone appearing to acquire a relative immunity through repeated mild infections. Great importance was attached by Pettenkofer to the height of the ground water in endemically infected regions; a low ground water, in his opinion, always coinciding with outbreaks of the disease. This relation between the disease and ground water apparently holds true for certain localities only and need receive no serious consideration.

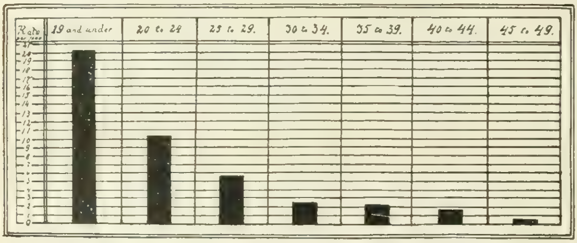

FIG. 1090.—Admissions for Typhoid Fever, per Thousand of Each Class, Divided According to Age, in the United States Army During the Seven Years 1890–96.

Negroes and other colored races undoubtedly possess an immunity, in their native countries, to typhoid fever. By some this is regarded as a racial characteristic; by others as an acquired immunity resulting from an attack of the disease during childhood. In India the blood of the natives has been recently shown to give, in most instances, a positive reaction with Widal's test. In our own service the disease is undeniably less frequent among the negro troops than among the whites. For the period 1867–83 the admissions per thousand white soldiers, for typhoid, not counting typho-malarial fevers as then recognized, amounted to 3.58, while the admissions for colored troops were 2.59 per thousand strength. For the year 1887 the admission rate for white soldiers amounted to 4.25, and for colored soldiers .93. During the decade 1887–96 the admission rate for white soldiers amounted to 4.74, and for negroes 2.43. It is interesting to note that for our few Indian soldiers, during this period, the admission rate for typhoid was only .47. During the year of war (1898) the relative insusceptibility of negro troops as regards typhoid fever was especially noticeable, the admission rate being 93.24 per thousand white and 27.64 per thousand colored troops—this, too, in spite of the fact that as a class the negro regiments saw harder service. On the other hand, when the disease has actually occurred the case mortality has been much higher among the negroes than among the whites. Typhoid fever occurs only exceptionally among the native troops in India, and their immunity as compared with the immunity of white soldiers serving in that country has long been noted. As illustrating how great this difference in susceptibility really is, it may be stated that, in 1893, of the forces in India, typhoid fever was responsible for 1.41 per cent. of the sickness and 42 per cent. of the mortality among the English soldiers, and for only .03 per cent. of the sickness and .4 per cent. of the mortality among the native forces. For the white race, nativity appears to be a factor of some slight importance. In the United States army, during the seven years 1890–96, the admission rate for typhoid fever from the native-born Americans, per thousand strength, was 5.69, for the soldiers of German nativity, 5.41, and for the soldiers born in Ireland, 5.02.

Typhoid fever is especially a disease of young soldiers. How much greater their susceptibility actually is can best be appreciated by reference to the accompanying diagram (Fig. 1090), in which the number of admissions are seen to decrease arithmetically by almost exactly one-half during each five-year period up to the age of thirty-five. Not only are young men more liable to contract this disease, but the mortality, also, among those affected is higher. Thus for the period 1890–96, in our army, the deaths per thousand of each class were as follows:

Age.	Death rate.
19 years and under	3.32
20 to 24	.95
25 to 29	.69
30 to 34	.23

The case mortality for this period was 16.02 per cent. for soldiers nineteen years of age or under; 9.21 per cent. for those twenty to twenty-four years of age, and 8.89 for those thirty to thirty-four years of age.

Length of service, in which factor age must of course be considered to enter, also markedly influences the occurrence of typhoid. The report of the surgeon-general for 1885 shows the relative prevalence of this disease, excluding small fractions, among men of different periods of service, to be as follows:

Length of service.	Percentage of cases.
6 months and under	48.0
Over 6 and under 12 months	16
Over 1 and under 2 years	14
Over 2 and under 3 years	5.5
Over 3 and under 4 years	4.5
All over 5 years	7
Length of service not stated	4.5

In respect to English soldiers in India, Eyre and Spottiswoode state:

"The susceptibility of young soldiers to this fever is clearly shown in the length of residence in India; for while the death rate from typhoid was 4.98 per thousand in the first and second years' service, among those in their third to sixth years and seventh to tenth years it was 1.55 and .55 respectively." The report of the Sanitary Commissioner of India for 1896 states that out of the total number of deaths at all ages from enteric fever, 78 per cent. were between twenty and twenty-four years of age and 36 per cent. were in the first year of residence. In India, the prevalence of the disease appears to depend chiefly upon the amount of susceptible material presented.

The influence of the branch of service upon the prevalence of typhoid fever is by no means small. For the period 1867–83 inclusive, the admission rates per thousand strength were as follows: cavalry, 19; infantry, 4.6; artillery, 2.5. For this period the cavalry thus suffered more than seven times as much from typhoid as did the artillery, and nearly five times as much as the infantry, while its death rate was more than three times greater than either of the others. This great difference was largely due to the active field service against Indians required at that time of mounted troops. For the seven-year period 1890–96, the admission rates per thousand strength were 8.03 for the cavalry, 5.74 for the infantry, and 4.74 for the artillery. In time of peace the personnel of the medical department is affected less than any of the above arms of the service; but during the war with Spain it suffered more than twice as much as any of them.

Overcrowding among troops certainly predisposes to epidemic typhoid fever; Marvaud gives figures to show that in the French army the mortality from this disease bears a well-defined relationship to the number of men aggregated at a post. In camp, the effects of overcrowding are particularly noticeable. This is perhaps due in part to a lowered vital resistance in the individual, but is probably chiefly dependent on the greater intensity of the infection resulting from the rapid propagation of the typhoid bacillus on a soil more highly contaminated with organic material, on which it possibly acquires more virulent qualities.

Uncleanliness of person and surroundings is a powerful factor in the development of the disease among troops. Particularly is this the case with regard to the care and disposition of the excreta, the most important and difficult problem presented to the military sanitarian in the field. The common method of disposal of excreta and refuse in camp—by pits—offers many facilities for the development and spread of the specific micro-organisms. All collections of filth are liable to contamination and hence to become foci of infection. In garrison the accumulation of organic matter under floors, together with the seepage of moisture as a result of the use of excessive amounts of water in cleansing, affords an excellent medium for the development of the microbe.

The influence of great fatigue as a factor in the occurrence of typhoid has been particularly noted by medical officers in foreign services. The arduous and exhausting manœuvres which take place yearly in all the larger European armies are invariably followed by outbreaks of typhoid. It is well known that by over-exertion the bactericidal power of the blood is diminished and susceptibility to disease greatly increased. Coustan mentions, as applying in this connection, the experiments of Charrin and Roger, in which rats made to turn a wheel until exhausted succumbed readily to inoculation with an attenuated culture of anthrax, while similar animals not so exhausted resisted the same inoculation.

Insufficient or improper food, through the malnutrition or digestive disturbance which results from its use, may facilitate the invasion of the organism by the typhoid bacillus.

Prophylaxis.—In the prevention of an epidemic of enteric fever among troops in garrison, a pure water supply is of the first importance. If the water supply be regarded as liable to pollution it should, in garrison, be filtered through the Berkefeld apparatus before being used for drinking purposes. In the field, and sometimes in garrison, water is best sterilized by boiling—preferably by the Forbes apparatus. If the water is originally pure, as water in springs, deep or artesian wells, or unpolluted surface waters, it will only be necessary to insure against its contamination before use. With troops in camp, while the water should be good, an early and correct diagnosis of the cases of this disease which first appeared is quite as essential. Since in camps enteric fever is more directly propagated from the sick, and the latter can through their discharges soon disseminate the disease through large bodies of troops, the prompt recognition and isolation of these cases, with the disinfection of their excreta, equipments, tentage, and surroundings, is of the greatest importance. As already intimated, the diagnosis of this disease is frequently a matter of much difficulty and may be impossible in all instances, but constant watchfulness on the part of medical officers will reduce this error to the minimum. The board investigating the typhoid epidemics prevailing during the war with Spain concluded that less than half of the cases of this disease which occurred were correctly diagnosed; but stated its opinion that, in recognizing this proportion, the army surgeon probably did better than the average physician throughout the country does in his private practice. Any such error of diagnosis, however, implies too great reliance upon the mere clinical symptoms of enteric fever—which, it has been stated, are frequently modified or largely lacking—and a too infrequent use of modern and more precise means of diagnosis, as found in the Widal test with blood serum and the diazo reaction in the urine. It is obvious that under many conditions of military service, particularly with marching troops, the former test can scarcely be applied, but in a fixed camp or garrison it can always be carried out—and the technique of the diazo reaction is possible under any circumstances. These tests should be habitually applied to every case presenting fever the nature of which is not promptly and definitely recognized as being other than typhoid. Since the Widal and diazo reactions may not be given at certain stages of enteric fever, they should be repeated one or more times in possibly suspicious cases.

When typhoid fever is recognized as existing, the affected individual should promptly be isolated. If in garrison, the clothing and bedding of the patient, together with the water-closet or latrine used by him, should be disinfected. . If the case occurs under canvas these precautions are required, and in addition the disinfection of the clothing and bedding of those sheltered with him should be sterilized. The tent itself should be disinfected. If possible the camp, or at least that of the company organization in which the case occurred, should be moved. If this be not possible, the site occupied by the infected tent should be vacated, policed and exposed to the sun. It should not again be occupied. In many instances it would, in addition, be desirable to freely scatter fresh lime over the former tent area.

Since many cases of enteric fever in camp will not be recognized, it should be the rule to regard all human excreta as infected, and, where a camp has a permanency of more than three or four days, systematically to carry out measures for the destruction of its presumably noxious qualities. The cost of an epidemic of typhoid will be many times the additional expense of these justifiable precautions. In all camps of any permanency the use of excavated latrines should be prohibited, and either the trough system or crematories, as now used in our army, provided. Under the same conditions, urine tubs should be provided for night use and their utilization enforced. Careful police of the camp, with cremation of refuse, should be carried out, to limit soil contamination and prevent the development of the fly plague. A careful sanitary police is very effective in preventing the development of these insects in very great numbers; but where the plague actually exists the only recourse is to abandon the infected area for a new site, preferably to be located to the windward and at a distance of at least two miles.

Other general methods of prophylaxis consist in the allotment of abundant space in the arrangement of the camp; the free exposure of the interior of tents—and of their contents—to sunlight and fresh air; cleanliness of person on the part of the troops; an abundance of good food and, in time of epidemic, the avoidance of exhausting drills and exercises. It is important that a presumably infected camp site should promptly be abandoned; though if troops be allowed first to become generally infected the procedure is not as efficacious in controlling typhoid fever as in some other diseases.

With respect to the measures to be applied to prevent further spread of the infection from the sick, the proper disinfection of the excreta is of the first importance. All discharges should be received in a solution of milk of lime. The nates of the patient should be cleaned with paper and afterward with a bit of compress cloth wet with a dilute disinfectant solution. The bed pan should be covered with rubber sheeting and removed at once. In garrison, the contents of the bed pan should be thoroughly mixed and allowed to stand for half an hour before pouring into the slop hopper; in the field it should be burned at once. The practice of burying typhoid discharges, after measures of disinfection by chemical means, is strongly to be deprecated. In certain instances all the bacilli undoubtedly will not be destroyed, and it has been shown that they not only develop in organically polluted ground but may grow upward through a considerable depth of earth. Even if buried deeply there is always a possibility of their future disturbance. Whether in camp or garrison, the cloth compresses used to cleanse the patient should be destroyed by fire. The bed pan, rubber cover, and slop hopper should be cleansed with disinfectant solution, and the two former wiped dry. Both should be placed in a closed receptable to prevent access by flies. All sputum should be received in spit cups containing a disinfectant solution. Feeding utensils should be cleansed in boiling water immediately after use, and any uneaten remnants of food at once disinfected by burning or scalding. All bed linen, body clothes, and towels soiled by discharges should be immediately rolled in a clean sheet wet in bichloride solution, and removed for appropriate disinfection. Bed spreads and blankets should be sunned and aired as often as possible. They should not be shaken any more than is absolutely necessary. Bed and body linen should be changed daily; rubber sheets should be used over the mattresses. Flies should be kept away from the patient, not only for his comfort, but to prevent the transmission of the disease to others by their agency.

After attending to the wants of a typhoid patient, the hands of the attendant in each instance should be rinsed in a disinfectant solution and then washed in warm water, using soap and a nail brush.

The urine of patients convalescent from this disease should be examined at frequent intervals for the typhoid bacillus. Return of convalescents to duty or quarters before this bacillus has been absent from the urine for at least one week should not be permitted. To effect the sterilization of the urine, where this bacillus is present, Richardson and others recommend the use of urotropin, in doses of gr. x. three times a day. Salol and other substances appear to have little value for this purpose.

Preventive Inoculation.—The problem of preventive inoculation against typhoid fever, now receiving much attention, has a special importance for the military sanitarian. Bokenham endeavored to produce a prophylactic and curative serum by the immunization of horses through the repeated injection of living and dead cultures of the bacillus; but the serum thus obtained was not of sufficiently great potency to give it a practical value, and no means could be found of precipitating or concentrating what strength the serum contained. Pfeiffer, Wright and Semple, and others, then endeavored directly to produce in man the immunity which it was shown could be created in animals. At first these investigators cultivated virulent cultures on agar, making up an emulsion of these cultures with bouillon so that each cubic centimetre contained about 2 mgm. of fresh agar growth. The microbes were then killed by exposure to a temperature of 56° C. for several hours. Of this emulsion 1 c.c. was used as a dose, the liquid being well shaken. Recently Wright has attained more satisfactory results by cultivating the bacilli directly in bouillon. After incubation at 37° C. for a period of from fourteen to twenty-one days, the culture is sterilized by exposure to a temperature of 60° C. for five minutes. This is done by drawing the emulsion into small sterile tubes, which are sealed and placed in a beaker of cold water which is gradually raised to the desired temperature, and this is maintained for the period above noted. Agar tubes are then inoculated with the material to make sure of its sterility. Before injection, .5 per cent. of lysol is sometimes added to neutralize any accidental contamination. The amount used for human inoculation is two-fifths of the minimum amount which would be fatal to a guinea-pig weighing 250 gm. The immunizing material appears to be valuable rather on account of its antimicrobic than its antitoxic properties.

While the reaction following the inoculation is usually slight, it is at times somewhat severe. Rigors, nausea, and a tendency to syncope sometimes occur. There is a well-marked local reaction, which, however, never advances to suppuration. Where the inoculation is successful, the blood serum acquires the specific agglutinative property to a marked degree. Cameron found in his own case that at the end of twenty days the agglutinating power of his blood serum was increased forty times; and an increase to this extent has been shown by other observers to be a common result. In general, the agglutinating property is equal to that conferred by an attack of the disease itself. It is not known how long the influence of the inoculation persists; and when a protection lasting more than two years is desired, it is recommended to insure a good reaction by repeating the inoculation after an interval of one week.

At present, experience with these inoculations has not been sufficiently comprehensive to warrant the drawing of exact conclusions. The inoculations have been carried out on a considerable scale, however, with the sanction of the British military authorities, on soldiers voluntarily submitting to the operation before leaving for the recent scene of hostilities in South Africa. Foulerton states that reports so far received from South Africa show that typhoid fever has occurred at the rate of six to the thousand among the inoculated and nine to the thousand among the uninoculated. Figures given by Wright based upon 11,295 British soldiers in India show that .95 per cent. of the inoculated contracted the disease where 2.5 per cent. of the uninoculated were attacked. These results, while not brilliant, are certainly encouraging, and render the method well worthy of general use among young soldiers; particularly since the inoculation, when properly performed, is quite free from danger.

TYPHUS FEVER.—*Occurrence.*—A chapter might be devoted to the historical pathology alone of typhus or spotted fever. The disease is as old as the disputes of nations, and has prevailed in formidable epidemics among troops in the field from 400 B.C. down nearly to the present time. During peace it has always been of comparatively subordinate importance, although its occurrence in armies has given rise, from time to time, to disastrous outbreaks among the civil population. It is known to have prevailed during the Peloponnesian war; and in 1489 it destroyed 17,000 of the troops of Ferdinand at the siege of Grenada. In 1528, at the siege of Naples, over 5,000 of the French nobility lost their lives from typhus in a period of about three weeks, and the French army of 30,000 men was almost destroyed. In 1542, in the German army at Ofen, according to Hauser, typhus claimed 30,000 victims. Before Metz, in 1552, the besieging Spanish army lost 30,000 men in less than two months, compelling the abandonment of the siege. The roads taken by the retreating army were said to have been lined with the dead and dying. In 1556, it decimated the army of Maximilian II. In 1620, the Bavarian troops serving in Bohemia lost over 20,000 men from spotted fever. In 1628 and 1632 the disease ravaged the Swedish army. Both the Royal and Parliamentary armies in England, in 1643, suffered severely; in the wars of Louis XIV. it caused enormous losses in the French army. At the siege of Torgau in 1760, it is said that over 30,000 men, out of a total of 35,000, died of this disease in a few months. Typhus is reported as having been one of the great factors in the mortality of our troops during the Revolution; and in 1790 the losses among the Russians from this disease were so great that operations against the Turks had to be suspended. In 1799 typhus decimated Genoa and the French force besieging it. The greatest recorded ravages of this disease, however, occurred during the wars of the first Napoleon. At Saragossa, out of 100,000 people, 54,000 died, chiefly from epidemic typhus. At Dantzic and Wilna, in 1803, and during the retreat from Moscow, vast numbers of French troops are recorded as having perished from typhus. In May, 1812, the Bavarian allies of the French mustered 28,000 men; in February, 1813, it is said that this disease had left but 2,500 to bear arms. In August, 1813, the first Prussian army of 60,000 men had lost one-sixth of its strength from an epidemic of typhus. Murchison states that in Mayence alone, of the 60,000 French troops composing the garrison in 1813–14, no less than 25,000 died of typhus in six months. According to Rawlinson, of the French armies around Paris, after the retreat from Russia, 40,000 men are recorded as having died of typhus in six weeks, one-fifth of the remaining force being sick. This disease raged in all the contending armies during the Crimean War, particularly among the French troops. Aitken says: "In the spring of 1856 it was computed that more than 17,000 men of the French force perished in less than three months, chiefly from typhus." Baudens declared that of the typhus cases in hospital in February, 1856, two-thirds were devoted to certain death. The deaths during this outbreak among the French medical officers amounted to 48, and there was scarcely one that escaped attack.

Typhus undoubtedly did not occur during the Civil War, although there were a small number of cases diagnosed as this affection. These were undoubtedly fulminant typhoid. It prevailed among the French troops in Mexico, especially on board the ships which conveyed the colored contingent from North Africa. Coustan says that the French troops in Mexico "suffered a cruel loss." In 1862–63, and again in 1867, typhus attacked the French garrisons in Algeria; Marvaud stating that of one body of 3,500 troops, 1,200 died. Its existence during the Franco-German War in 1870–71 is disputed. During the Russo-Turkish War in 1878 it was said that at one time the cases of typhus were so numerous in the Turkish army as to threaten its disorganization, and the conditions in the Russian army were not much better. After the capture of Plevna, according to Coustan, 50,000 men out of a total of 120,000 died during the period of inactivity, and in May and June of 1879 it is stated that half the Russian forces near Constantinople were prostrated with this disease.

Typhus, in the military service, is essentially a disease of camps and sieges. Of late years typhus has lost much of its dangerous character. Its geographical distribution is not great, and at present, in time of peace, it occurs only among troops stationed in Southeastern Europe, where the disease is endemic. In the Russian army for the period 1890–97, the rates per thousand were as follows:

Year.	Admissions.	Deaths.
1890	0.6	0.04
1891	.9	.07
1892	1.8	.14
1893	....	....
1894	.7	.05
1895	.3	.03
1896	.3	.02
1897	.2	.02

In the Austrian army there were 9 cases in 1897, 4 in 1896, and 8 in 1894. There has been no well-authenticated outbreak of this disease in our army within the past half-century. A number of epidemics of typhus have, however, occurred in the civil population of the country—the infective agent being in every case imported from abroad.

Direct and Predisposing Causes.—The specific exciting cause of typhus fever has not as yet been isolated, though undoubtedly such a factor exists. Recently, in Russia, it is said that the disease has been experimentally produced by inoculation with the blood of typhus patients. It is universally admitted that the most important influences predisposing to its epidemic occurrence are want, misery, and hardship. Typhus appears to be largely favored by overcrowding and lack of proper ventilation. Cold weather, as shown in the Crimean War, indirectly promotes its occurrence among troops for these reasons. Viry notes that typhus was prevalent in public institutions in the city of Metz, in 1870, when it did not appear among the French troops living in shelter tents just outside the walls. Poor food, dampness, fatigue, and other conditions lowering the resistive powers—together with psychical depression—have much to do with epidemics of this disease.

Typhus fever is highly contagious, in the strict sense of the word; and there is probably no disease which has been proportionately more frequently contracted from the sick by their attendants. At Plevna, nearly all the medical officers were attacked; during the Crimean War 12.8 per cent. of medical officers and only .4 per cent. of line officers, among the French troops, died from typhus. The specific virus appears to be distinctly transmissible from the sick to the well through the surrounding atmosphere. While nothing is known of the causative agent, infection appears to occur by way of the air passages. The poison may be harbored by and carried from place to place in fomites. Jacquot, in speaking of typhus in the Crimea, says that "wherever troops affected with typhus have camped, the dejections and excretions which have saturated the ground are fatal to troops which follow them." The morbific agent appears to exist long in infected clothing and dwellings. The activity of the specific virus is favored by unsanitary conditions, and where the disease is introduced among troops which are poorly nourished and clothed and living under conditions implying overcrowding, there is every likelihood of an epidemic outbreak of the fever. The incubation period is variously stated at from six to fourteen days, though there appear to be some well-authenticated cases in which it was not more than from two to five days. The disease is most common during the period of youth and early maturity, as found in young soldiers; but the mortality is lower than among those of greater age.

Prevention.—It is manifest that the prophylactic measures against the disease are those that aim to prevent its introduction from without, and those that are designed to eliminate all local conditions favorable to its development. Quarantine against infected points should be rigorously maintained. When the disease occurs among troops in garrison, the sick and well should promptly be placed under canvas; for the influence of fresh air upon the virulence and vitality of this disease is undoubtedly of the highest importance. The command, if large, should be broken up into smaller bodies. Especial attention should be given to the prevention of overcrowding, to insuring the abundance and proper preparation of food, to the avoidance of fatiguing exercise, and to the maintenance of strict sanitary police. Careful watch should be kept for suspicious cases, and these should be at once isolated. It should not be forgotten that the aggregation of large numbers of the sick increases greatly their mortality, as well as the danger to the attendants. Tent hospitals should preferably be used, the supply of fresh air being unlimited and the floor space allowed to each patient being about two hundred square feet.

As the contagion is especially virulent near and about a patient, attendants should avoid inhaling the emanations or exposing themselves unnecessarily to such inhalation, unless protected by a previous attack. They should not stay in the immediate vicinity of typhus patients longer than necessary and should never sleep in a ward. They should take plenty of sleep and good food, and should frequently employ disinfectant solutions on the face and hands. The attendants, like the sick, should of course be quarantined. Careful disinfection of bed and body clothing and excreta is always called for. The barracks or wards, as well as all articles of furniture, clothing, or equipment contained in it, should be disinfected and thoroughly aired after removal of the patient.

YELLOW FEVER.—*Occurrence.*—Yellow fever is essentially a disease of tropical and sub-tropical countries, and is ordinarily restricted to well-defined geographical limits. Bodies of troops serving within these limits for any length of time have uniformly been more or less affected by it. In 1648, "there occurred in Havana, and in the fleet of Don Juan Pujados, a great pest of putrid fevers which remained in the port almost all summer. A third part of the garrison and a larger part of the crews and passengers of the vessels died." The disease was extremely fatal among the British troops which subsequently captured Havana; and it is interesting to note that the regiment of loyal Americans recruited for this expedition, largely from the south, was least affected. In 1740, in the expedition against Carthagena, its effects were most disastrous. In 1780 a force of 8,000 Spanish soldiers was landed at Havana, and in two months it lost 2,000 men from this disease. In Hayti, during the rebellion of the blacks, the French army of veterans was practically annihilated by yellow fever. Of this epidemic Lemure wrote: "In 1802 an army under the orders of General Leclerc embarked for San Domingo. The effective strength, on leaving Brest, was 58,545 men. In four months 50,270 men were dead; chiefly of yellow fever, which gave 82.5 per cent. of the mortality. Of the 8,275 men remaining, 3,000 were sick or wounded. In 1809, seven years later, this army was reduced to 300 men, who returned to France." The French also suffered severely during their occupation of Mexico. According to Coustan, there were 1,705 cases; the fever breaking out six days after the troops landed at Vera Cruz. During the Civil War there were, in the Union forces, 1,371 cases and 436 deaths; and in 1867 the disease attacked a number of Southern posts and caused 1,520 cases with 453 deaths. For the period 1868–84 the disease recurred almost annually among such troops as were stationed in the South, the average for the whole army for this period, per thousand strength, giving a rate of .78 for admissions and .33 for deaths. For the period 1885–96 inclusive, there were no cases of yellow fever in our service. In 1897 there were 7 cases with 3 deaths; and in 1898, at Santiago, there were 604 cases with 70 deaths. For the period 1868–98 the rate for admissions was 1.17, and for deaths .26 per thousand strength. The Spanish army in Cuba has always suffered severely from this disease, especially during the epidemics of 1876, 1877, and 1896. The British and French troops stationed in the West Indies, have been repeatedly attacked.

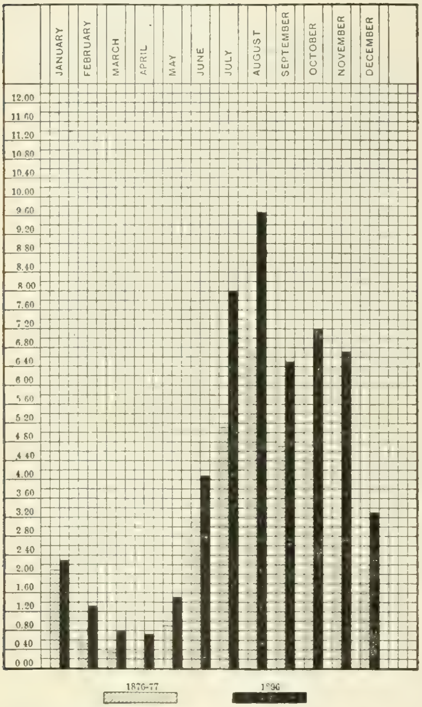

FIG. 1091.—Distribution by Months of Deaths from Yellow Fever in the Spanish Army in Cuba, per Thousand Strength, During the Epidemics of 1876 and 1896.

Nature and Mode of Dissemination.—With regard to the nature of the materies morbi of yellow fever nothing is as yet known, though investigations by many army medical officers have been, and are now being, vigorously prosecuted; hence it is impossible to say definitely whether it is disseminated by water, air, or insects. It is safe to regard the excreta of a yellow-fever patient as especially infectious. There is an abundance of evidence to show that yellow fever may be transmitted in clothing, merchandise, or similar articles. Such fomites as have been in the immediate vicinity of yellow-fever patients are to be regarded as especially dangerous. Infected habitations in the yellow-fever belt are probably the chief points from which the disease is spread. Apparently, the yellow-fever patient, removed to good surroundings, is not so greatly to be feared as is the place in which the sufferer contracted his infection. Experience has shown that, with proper precautions, those in attendance on the sick are not especially liable to contract the disease; and yellow-fever patients have often been treated in the same wards as susceptible patients without the disease having been disseminated. Such practice, however, is of course highly undesirable. While the patient, therefore, does not ordinarily affect others directly, he undoubtedly gives off, presumably in his discharges, the virus of the disease, and this is capable of infecting a particular locality and thus of giving rise to the disease in others. Outside the body the micro-organism probably undergoes development in the soil. The incubation period of the disease is short, varying from one to five days.

Predisposing Causes.—Absolute immunity to yellow fever is not possessed by any race as a peculiar characteristic; though relatively speaking, those individuals who are permanent residents in the endemic zones exhibit less liability to contract it than do strangers newly arrived from colder latitudes. In general terms it may be considered that the susceptibility to, and mortality from, yellow fever vary directly with the distance from the equator of the place of nativity and residence of the individual. According to Barton, of each 1,000 deaths from yellow fever which occurred in New Orleans in the epidemic of 1853, the distribution of mortality was as follows:

Native Creoles	3.58
Strangers from West Indies, Mexico, and South America	6.14
Strangers from Southern United States	13.22
Strangers from Spain and Italy	22.06
Strangers from Middle United States	30.69
Strangers from New York and New England	32.83
Strangers from Western United States	44.23
Strangers from France	48.13
Strangers from British America	50.24
Strangers from Great Britain	52.19
Strangers from Germany	132.01
Strangers from Scandinavia	163.26
Strangers from Austria and Switzerland	220.08
Strangers from the Netherlands	328.94

Long ago Blair wrote that among the West India islanders in the Seamen's Hospital at Demerara, Guiana, the percentage of deaths from yellow fever was 6.9; among French and Italians it was 17.1; among English, Irish, and Scotch, it was 19.3; among Germans and Dutch it was 20; among Swedes, Norwegians, and Russians it was 27.7. It has been thought that the Creole and the African, irrespective of place of birth or of residence, possess a racial immunity to yellow fever. This, however, does not appear to be the case. Such a relative immunity is probably only the result of an attack of the disease itself, which in early life may be so mild as scarcely to be recognized; or, to a much less degree, it may be due to the transmission of a relative unsusceptibility from ancestors immunized for generations through attacks of the disease.

It should be noted that the immunity to this disease undoubtedly possessed by many natives in the yellow-fever belt is more or less completely lost after they remove to cooler latitudes, and that such individuals on their return to the zone of endemic yellow fever often exhibit a susceptibility equal to that of total strangers to the district. There is, therefore, no reason to believe that the negro primarily possesses any greater powers of resistance than does the white man under the same conditions, or that the negro born and resident in cold climates is as unsusceptible as the negro from the yellow-fever belt. An acquired or an inherited immunity is the essential factor. It should be noted that yellow fever prevailed among the negro troops at New Orleans during the Civil War and caused considerable mortality. Thus also for the year 1898, the rates in our army for this affection, per thousand strength, were as follows:

	Admissions.	Deaths.
White troops	9.40	1.04
Colored troops	59.19	7.51

The negroes recruited for our service are rarely drawn from districts in which the disease has prevailed. The great difference above noted in favor of white troops, however, is largely to be explained by the fact that the colored troops of our army were nearly all present at Santiago, while a much less proportion of the total white troops were so exposed. Further, one colored regiment, on account of its supposed relative unsusceptibility to this disease, was selected to do guard and police work at the yellow-fever hospital, thus largely increasing its opportunities for infection. A fair comparison of the susceptibility of the unacclimated white with that of the negro native to the yellow-fever zone may, however, be drawn from the British troops in the West Indies. For the decade 1888-97 the rates for yellow fever, per thousand strength of these troops, were as follows:

	Admissions.	Deaths.	Constant sickness.
Europeans	3.0	1.66	0.16
Non-Europeans	.4	.15	.02

Prophylaxis.—As a preventive of the occurrence of yellow fever among troops, expeditions into an endemically infected district should not be carried out during the rainy season. Troops intended permanently to garrison infected points will be with advantage recruited from the native and immune population. Whether in camp or in garrison, general prophylactic measures of great importance have reference to careful sanitary policing, free ventilation, an avoidance of overcrowding, and a pure water supply, with proper means of maintaining personal cleanliness. During the Civil War the comparative freedom from yellow fever of Union troops garrisoning New Orleans was regarded as chiefly due to the vigorous sanitary measures introduced by General Butler. Recently, in the occupation of Cuba, the value of proper sanitation in controlling the disease has been strongly demonstrated. Troops should be prohibited from entering infected towns, and particularly from entering houses and shops. When an epidemic occurs among the surrounding population, a careful quarantine should be maintained. With the outbreak of the disease among the troops all cases should be promptly isolated, preferably in tents. All discharges from the sick, especially the vomit and excreta, should be disinfected; if possible, by fire. The clothing and equipments of the soldier, and those with which he may have come in contact, should be disinfected; as should the tent or barrack in which the case occurred. If possible, the troops should be moved to a locality in which the fever has not been known to occur. In this country troops have habitually been transferred from southern stations to Atlanta, when an outbreak of the disease was apprehended. If such a locality is not available, the troops should be moved to high ground—preferably to an elevation of at least fifteen hundred feet. Moving camp even a mile or so may avert an epidemic, and this procedure should be repeated upon the appearance of every new case. Depopulation of an infected area is essential, a fact repeatedly demonstrated in our own service; as at Fort Brown in 1882 and at Santiago in 1899. If the disease appear on board a transport, the sick should be treated on deck and landed as soon as possible. A predisposition to the disease appears to be caused by fatigue, especially when combined with exposure to the sun; by the immoderate use of alcohol, and by insufficient or improper food. No prophylactic medication is known to be of value. Various methods of preventive inoculation have been devised, notably by Freire and Sanarelli, but experience has shown these to be without effect.

DISEASES DUE TO INTEMPERATE OR IMMORAL HABITS

ALCOHOLISM.—The attitude of the soldier toward the use of intoxicants is largely determined prior to his entrance into the military service. That the majority of such soldiers as actually become drinking men after entering the army, do so as a result of social environment, cannot for a moment, however, be doubted. To drink and ask the companionship of others in consuming alcoholic beverages is the first step toward the development of the drunkard in the army, as in civil life. The idea that social superiority attaches to an ability to consume large quantities of alcoholics still exists to a certain extent among a few soldiers of a lower class; and by such, a novice in the art of drinking may be assailed with ridicule and contempt. Such men are largely responsible for the idea which sometimes prevails among recruits that a physical tolerance of alcohol is an essential attribute of the seasoned soldier, and that only he who is able to imbibe his share of intoxicant without apparent effect has demonstrated his fitness to enter upon the profession of arms. Besides the above class, a number of soldiers undoubtedly acquire the habit of alcoholism through favorable opportunity, particularly if they are men without aim or purpose in life beyond the perfunctory accomplishment of routine duties; men who are possessed of no internal resources for their amusement, and to whom the normal military existence is burdensome, dull, and monotonous. A certain class of susceptible individuals appear to be markedly influenced in their use of alcohol by atmospheric conditions; and excessive heat, cold, and moisture have been observed to develop a latent desire for drink on the part of soldiers which would probably otherwise have remained dormant. A small number of periodical drunkards are true degenerates. Without apparent cause, in the face of promises and protests to the contrary and in spite of inevitable court martial, disgrace, and punishment, alcoholic excesses are begun and continued until exhausted nature brings the debauch to a close. Then follow deep contrition and humiliation, renewed and earnest promises of reform, and an apparently sincere attempt to repair the damage done to health and character; a period of steady habits, and again a sudden plunge into alcoholic excesses. A large proportion of inebriates, however, as found in the military service, are men of unstable mental equilibrium, indecision, and weak character. Such, under any conditions out of the ordinary, find the mental strain beyond their power of endurance and promptly seek relief in the nerve-benumbing effects of alcohol.

Frequency of Alcoholism.—In the army the abuse of alcohol is one of the most potent factors by which military efficiency is impaired; and in the past drunkenness has been largely looked upon as a distinctively military failing. Its influence, as well as its prevalence, however, is indifferently shown by statistics. All alcoholics do not enter hospital, and a certain proportion succumb to other affections, as gastritis, cirrhosis, and nephritis, in the occurrence and ultimate result of which the use of intoxicants may have played no minor part. Further, the term alcoholism includes many pathological conditions and their symptoms, these varying according to the quantity of alcohol taken and the frequency with which it is consumed. Chronic drunkenness occurs chiefly among old soldiers; and this class is naturally not proportionately represented on the sick reports as compared with younger men, among whom the use of intoxicants more frequently occurs in the nature of periodical excesses. Acute alcoholism not rarely terminates life, and even at as recent a period as the decade 1886–95 it stood sixth in order of importance in determining the annual mortality among white troops. The proportion of discharges and constant non-efficiency from this cause is, however, at all times low.

The amount of alcoholism in our service has steadily decreased in the past fifteen years; this having been accomplished through greater care in the selection of recruits, a growing sentiment in favor of temperance in the social class from which the soldier is drawn, greater efforts on the part of the authorities for the elimination of inebriates from the service, and, finally, through the establishment of canteens, the favorable influence of which is discussed subsequently.

The following table shows the prevalence of alcoholism in the military forces of the United States during the thirty years of peace 1868–97, inclusive:

Year.	Mean strength.	Number of cases admitted to hospital per 1,000 strength.	Number of cases of delirium tremens per 1,000 strength.
1868	47,472	32.59	
1869	35,221	37.70	
1870	31,831	38.20	
1871	29,430	45.80	
1872	26,844	47.50	
1873	27,909	49.40	
1874	27,021	58.10	
1875	23,575	68	
1876	24,886	64.50	
1877	23,707	59	
1878	23,381	59.40	
1879	23,964	65.10	
1880	24,004	61	
1881	23,222	57.60	
1882	23,239	68.70	
1883	23,439	66	
1884	24,034	62.10	
1885	24,138	53.50	1.57
1886	23,572	42.80	1.01
1887	23,841	46.70	.88
1888	24,726	40.20	.92
1889	25,008	41.40	.51
1890	24,234	40.70	.86
1891	23,269	40	.90
1892	24,203	37.20	.78
1893	25,287	33.80	.55
1894	25,376	30.90	.82
1895	25,204	30.10	.83
1896	25,119	28.80	.39
1897	25,417	27.80	.58

In 1898, during the war with Spain, the admission rate fell to 15.1; the more active operations and novelty supplying much of the desired excitement, while the unusual conditions undoubtedly attracted a superior and more temperate class of young men to the colors.

ADMISSIONS FOR ALCOHOLISM AND ITS RESULTS, PER 1,000 STRENGTH, 1885–97.

Year.	White troops.	Colored troops.	Total for the army.
1885	59.00	4.00	54.00
1886	50.21	4.67	47.09
1887	50.88	2.23	46.31
1888	43.97	4.55	40.12
1889	45.64	2.07	41.43
1890	44.45	5.59	40.73
1891	44.19	3.39	40.01
1892	41.19	8.35	37.23 *
1893	37.23	7.47	33.97
1894	33.79	4.79	30.94
1895	32.16	6.47	30.11
1896	31.20	5.70	29.06
1897	30.02	4.62	27.86
Decade 1886–95	42.37	4.89	38.69 *

* Including Indian soldiers.

The remarkable difference existing between the white and black troops of the United States service as regards the prevalence of inebriety is illustrated in the preceding table—statistics which cover extended periods and which show that there is approximately only one-tenth as much alcoholism among the negro regiments as among the white troops. Few colored soldiers are hard drinkers, and as far as beer and other malt liquors are concerned, there apparently exists a racial distaste for these beverages. It is well recognized that where negro troops replace white soldiers in a post, the canteen profits from beer and wine are greatly diminished while the sales of cigars and confectionery are proportionately increased.

This racial difference as regards the use of alcoholics is further shown by statistics for the British army covering the European and non-European troops in the West Indies. For the year 1897 the admission rate per thousand strength, for the former class, was 15.6, while the death rate was .74. For the native (negro) troops during the same year the admission rate from this cause was .6, while the death rate was *nil.*

As to the amount of drunkenness existing in foreign services as contrasted with our own, no accurate comparisons can be drawn, from the fact that abroad none but the severe cases of alcoholism appear on sick report. Drunkenness, however, is fairly prevalent in England and Germany—much less so among the Latin nations, who are comparatively free from alcoholic excess. In France, where absinthe is much employed, the rates are said by Laveran to be only about one-tenth as high as in the English service, and Viry states that for the fifteen years 1875–90 the deaths from the use of alcohol in the French army amounted to only 11.5 annually, a considerable proportion of these occurring in Algeria. In Italy and Spain the rates are even lower than in France, and during the occupation of territory by our troops as a result of the late war, it was a matter of frequent comment that an intoxicated Spanish soldier was rarely, if ever, seen.

In both the British and French services the amount of alcoholism is much greater among troops serving in the colonies than among those at the home stations.

Influence of Alcohol on Military Efficiency.—The effect of moderate drinking in the production of an increased amount of sickness is well illustrated by the data collected by Carpenter relative to British troops serving in India, based upon 17,334 moderate drinkers and 9,340 abstainers. Of the former class he found that 1 out of every 7.28 soldiers was admitted to hospital, whereas of the latter group but 1 out of every 14.47 was so admitted. Still more favorable to the abstinence class are the figures for the average number of days spent in hospital; the moderate drinkers losing 102 days per thousand as compared with an average for the abstainers of 36.4 days. According to an editorial in *The British Medical Journal,* the admissions to military hospitals in India, during the year 1891, amounted to 5 per cent. for abstainers and to 10.4 per cent. for all others. Madden states that in three benefit associations in England, during the five years 1884–88, there were lost by each laborer 26.20, 24.68, and 27.66 weeks through illness—an average of 26.18 weeks; while during the same period, in the "Sons of Temperance," which admits only total abstainers to membership, the average number of weeks lost by each member were 7.48—less than one-third the rate given in the other organizations.

As to the actual effect of alcohol upon the death rate, it is obvious, as already remarked, that military statistics furnish little information on this point, since only acute cases of intoxication are noted on the records. Chronic alcoholism, however, while it cuts no figure in military statistics, imparts a peculiarly grave character to all diseases occurring in drunkards, and does much, through the organic changes, local congestions, and nervous depression which result from the continued use of intoxicants, to bring about a fatal termination in any serious affection.

Alcohol is one of the most frequent causes of insanity and suicide in the military service. In civil life some writers attribute two-thirds of all mental diseases to alcohol, and it is said to be the chief cause of self destruction in England, Germany, and Russia. According to Madden, in the years 1878 and 1879 it was found that in 27 per cent. of all male lunatics in the asylums of Germany the mental condition could be directly traced to the use of alcoholics. In Austria, according to Gauster, 40 per cent. of insanity occurring in males could be ascribed to alcoholic excesses. In our military service no figures as to the influence of inebriety upon insanity are available; but for the seven years 1887–93, out of 134 suicides occurring during that period, alcoholism was officially reported as being the cause in 31.3 per cent.

With regard to the use of alcohol upon marching troops Rosse states: "The experience of the Ashantee War in 1876 shows that alcoholic drinks are hurtful. The men who did not touch the supplementary ration of rum presented a mortality and morbidity inferior to the other soldiers." This statement will be supported by all who have served with troops on campaign.

As to the effect of drunkenness upon military morals and the maintenance of discipline, no argument is required to show that the infractions of discipline are largely the result of alcoholic stimulation. It was noted of the British troops in India, in 1891, that of all minor offences 1.5 were committed by abstainers to every 6.7 committed by moderate drinkers. As expressed by Smart, "the medical and court-martial records after pay day, in all camps where whiskey can be procured, furnish data sufficient for insistence on its exclusion as the cause of much disease and many injuries and accidental deaths."

As summed up by Parkes: "When debarred from spirits and fermented liquids, men are not only better behaved but are far more cheerful, are less irritable, and endure better the hardships and perils of war. The courage and endurance of a drunkard are always lessened; but in a degree far short of drunkenness, spirits lower, while temperance raises, the boldness and cheerfulness of spirit which a true soldier should possess. If spirits neither give strength nor sustain it against disease, are not protective against cold and wet, and aggravate rather than mitigate the effects of heat; if their use even in moderation increases crime, injures discipline, and impairs hope and cheerfulness; if the severest trials of war have not been merely borne, but most easily borne without them; if there is no evidence that they are protective against malaria and other diseases, then the medical officer will not be justified in sanctioning their issue or their use under any circumstances."

Woodhull adds: "It is not necessary to insist, from theoretical or medical grounds alone, upon the mischief that alcohol causes soldiers. The observation of any officer of experience is enough. Liquor, besides weakening men physically, tampers with their will power, disturbs their temper, makes them less trustworthy even when sober, is at the bottom of almost every violation of discipline, and is the one agent that can convert a regular force into a mob. The absence of liquor usually means a clear guard-house. Abundant liquor means a heavy sick list, a large guard report, and a general feeling of doubt as to the command. It follows without saying that if the use of alcohol is hurtful in a personal and in a martial sense to the private soldier, who is the lowest unit in the military scale, it is very much more mischievous in its ultimate consequences when an officer, who is so potent with those beneath him, is its victim."

For the United States service the discussion of alcoholism would be incomplete without reference to the canteen, which, more than any other one factor, has brought about a reduction in drunkenness and its results.

This institution, officially known as the post exchange, had its origin in our service at Vancouver Barracks in 1880, but it was not until February, 1889, that the institution was recognized by the War Department, and rules and regulations for its establishment and government published to the army.

The purpose of the army canteen, as officially announced, is to supply troops with goods at a low rate of profit and to afford rational recreation and amusement to all enlisted men. The sale of ardent spirits is strictly prohibited therein; but commanding officers are authorized to permit light beer and wine to be sold by the drink, on week days, in a room set apart for the purpose, when in their opinion such action is promotive of temperance. Gambling of any character is forbidden. Each canteen is managed by an officer selected by the post commander for his fitness for the position, he being allowed one or more enlisted men as assistants; under recent orders civilians only being allowed to serve as barkeepers. As showing the favor with which the system was received, it is only necessary to say that in 1894, five years after its inauguration, there were 75 canteens in successful operation, and that during that year the total receipts were $1,417,079.62; of which sum no less than $304,649.91 were returned to the men as dividend profits.

The effect of the introduction of the canteen system upon the rates for alcoholism was prompt and marked. For the decade 1878–87 the average number of admissions for alcoholism and its direct results amounted to 64.28 per thousand of white troops. This rate diminished during the next ten years in proportion as canteens were gradually established at various posts, omitting fractions, in the following ratio: 44, 46, 44, 44, 41, 37, 34, 32, 31, 30. On observing the admissions for alcoholism for the seven years 1885–91 which immediately preceded the general establishment of the canteen system upon a satisfactory basis, it is found that a yearly average of 1,214.8 men found it necessary to apply for treatment from this cause; while for the six years 1892–97, after canteens had been generally instituted throughout the army, an average of only 928.4 men annually required attention for this reason—a reduction amounting to 23.6 per cent. In 1890 there were 17 posts at which the admission rate for alcoholism exceeded 10 per cent. of the strength. In 1891 the number of such posts had decreased to 11, and in the six subsequent years diminished at the following rate: 10, 7, 4, 5, 2, 2. This favorable showing for the army at large was duplicated in the case of each individual post, the introduction of the canteen failing in no instance to be promptly followed by a diminution of alcoholism. For certain stations this improvement was extraordinary. In 1889, Willet's Point had an admission rate for alcoholism of 222.97 per thousand. In 1890, the year when the canteen was established at that post, it fell to 157.50, and in the next year amounted to only 70.46. At Fort Spokane the amount of sickness resulting from intoxicants was reported by the surgeon as having diminished 50 per cent. during the six months following the institution of the canteen. At Fort Douglas, in 1888 and 1889, the total number of admissions attributed to alcohol amounted to about 85 per thousand strength; while during 1892–94 this rate fell to 52.95 per thousand strength; and such instances might be multiplied many fold.

As to the value of the canteen in the tropics as well as at home stations, in reducing alcoholism, all are agreed. A report by O'Reilly upon the condition of the British troops in Jamaica states that the canteen, from which the men can always procure beer, has been largely instrumental in the disuse of stronger spirituous liquors and in a lessening of the evils which followed the free use of spirits in the tropics. In referring to the condition of the Fourteenth United States Infantry at Manila, Cardwell expresses his belief that a great improvement shown in the figures for venereal disease and alcoholism in this regiment was due to the establishment of a canteen, kept under admirable discipline; and he adds: "Cool American beer as a substitute for the 'beno' of the native gin shops has a most beneficent effect."

The cases of delirium tremens will be accepted by all as furnishing reliable data by which the gravity of the admissions for alcoholism may be determined. It is, therefore, of interest to observe that, for the seven-year period above noted prior to the complete adoption of the canteen system, the average annual admissions for this cause, actual numbers, were 23.8; while for the six-year period of peace following the establishment of this system the average number of men admitted yearly for delirium tremens was 16.6, a reduction of 31.3 per cent. in this serious class of cases. It can scarcely be doubted that this remarkable decrease was chiefly influenced by the substitution of beer—a milder beverage, which rarely produces such effects—for distilled liquors, whose free use is well known to result in great mental excitement and nervous exhaustion.

It is recognized that alcoholism and insanity are closely related through the direct influence exerted by intoxicants in the production of mental aberration. Hence it is not surprising to find that the average number of cases of insanity annually coming under treatment was 35.1 for the seven-year period 1885–91, prior to the complete establishment of the canteen system, and only 24 as an annual average for the six subsequent years, 1892–97. These figures show a reduction in insanity amounting to 31.7 per cent. As to the number of days of service lost annually from insanity, the improvement since the institution of the canteen is even more marked. Figures for the years 1885 and 1886 are not available; but for the five-year period 1887–91, the average number of days lost was 1,563, while for the six years 1892–97 the service annually lost to the government from this cause amounted to only 924.5 days—a decrease of 40.9 per cent.

The canteen—for the maintenance of good order in which a commissioned officer is held responsible—is an aid to discipline as well as to the health and morals of troops. It provides a resort which, while under thorough military control, offers inducements to the men to remain at home and spend their idle time within the limits of the post; this condition obviously being far preferable to the one formerly existing, when the nearest and most generally patronized places of amusement and refreshment were the grog shops, usually with brothel annexes, which marked the limits of each military reservation. Except with the most dissolute class of men, the soldier is well satisfied to patronize the canteen to the exclusion of outside saloons; knowing, as he does, that he receives good value for his money in articles of excellent quality, and fully appreciating that the profits of the institution ultimately accrue entirely to his benefit, and are not, as is the case with outside establishments, diverted to the advantage of others. Besides the congenial resort which it furnishes, the influence of the profits of the canteen in promoting contentment among troops can scarcely be overestimated, contributing as they do to improvement of the food, to the attainment of wholesome amusement, and to the provision of much by which the soldier's life is made less irksome and he himself rendered more efficient in the performance of his military duties. The best index of the contentment of troops is to be found in the rate of desertions, since it is obvious that the soldier who is well satisfied with his lot will not endeavor to escape from the performance of his military obligations. That the canteen system has, from this standpoint, operated to the general welfare of the men is undoubted, the desertions and percentage of desertions in the regular army, from 1885 to 1897 inclusive, being as follows:

Year.	Average strength.	Deserted.	Per cent.	Year.	Average strength.	Deserted.	Per cent.
1885	24,816	2,626	10.6	1892	24,869	1,410	5.7
1886	24,365	2,012	8.3	1893	25,670	1,632	6.3
1887	24,438	2,525	10.	1894	25,661	926	3.6
1888	24,790	2,678	11.	1895	25,209	1,341	5.3
1889	25,564	2,730	11.	1896	25,143	858	3.4
1890	24,930	1,922	7.7	1897	25,300	726	2.9
1891	24,525	1,398	5.7				
Average for seven years before canteen system was thoroughly established			9.18	Average for six years after canteen system was thoroughly established			4.53

From the above table it is observed that during the first year after the canteen system was authorized the rate of desertions fell 26 per cent., while during the next year, as the system was more generally established, the rate was further reduced to 49 per cent. For the five years previous to the establishment of the first officially recognized canteen the number of men annually deserting from the service, per thousand strength, amounted to 101; while for the eight years immediately subsequent to the institution of this system the annual number of desertions was reduced to 50 per thousand strength. The decrease noted has been practically progressive, and for the two years immediately prior to the war with Spain scarcely one-fourth the number of men, as compared with the three years immediately prior to the introduction of the canteen system, found the military service so uncongenial as to desire to escape from completing their terms of enlistment. These results are certainly most gratifying, and there is no reason for believing that with the development of the canteen along its legitimate lines of growth a still further decrease in the present small rate of desertions may not be confidently anticipated.

Drunkenness is certainly prevented by the constant military supervision to which the canteen is subjected. The men themselves are usually careful not to indulge in alcoholics to the point of inebriety; while such few individuals as are inclined to be forgetful of the dangers of excess are usually restrained by companions, or by those connected with the canteen, from passing the bounds of actual intoxication. Should such a condition actually result the drunken individual is rarely left to his own devices or permitted to become offensive, but is usually prevailed upon by others to return to barracks without committing any breach of discipline. Hence, brawls and disturbances, with resulting court martial, have, since the introduction of the canteen system, become relatively infrequent, and pay day, formerly synonymous with debauchery and riotous disturbances, is now scarcely to be distinguished by its effects from any other day. As illustrating the marked reduction of convictions for drunkenness and for complications arising therefrom, since the establishment of the canteen, the following figures, from the reports of the judge advocate general, are of interest:

Year.	Total number of trials and convictions in the army.	Number of trials and convictions for drunkenness and for conditions arising therefrom.
1886	1,640	342
1887	1,730	289
1888	1,999	357
1889	1,752	423
1890	1,907	407
1891	2,000	417
1892	2,198	228
1893	2,189	163
1894	1,728	120
1895	1,486	142
1896	1,384	168
1897	1,245	143
Average for the six years 1886–91	1,838	372.5
Average for the six years 1892–97	1,605	160.6

From the above figures it is evident that coincident with the thorough establishment of the canteen system there has occurred a decrease, amounting to considerably more than one-half of the drunkenness which formerly tended to the impairment of discipline, to the demoralization of individuals, and to the occurrence of assaults, injuries, and deaths. It is idle to deny that this excellent result has been largely due to the attraction furnished by the canteen, combined with the military discipline which prevails in that institution and which reduces to a minimum the possibility of dangerous alcoholic excesses.

The opportunity given the men of purchasing light, nutritious lunches in the canteen is also certainly of much benefit. Many articles of food not obtainable in the company mess are thus brought within reach, and the monotony which often pertains to company cookery may in this manner be agreeably interrupted. It is probable, too, that this feature does much to prevent the intemperate use of alcoholics. The gastric cravings of hearty and idle men are thus satisfied, and a sandwich with the beer largely decreases the desire for an additional quantity of the latter.

It is claimed by the advocates of total abstinence that through the sale of beer in the canteen the health and morals of the soldiers are impaired; that such tacit encouragement on the part of the government favors indulgence in alcoholics, and that drinking habits are thus formed by those who might otherwise have remained sober men. These objections are purely theoretical, and are at variance with facts as observed since the establishment of the canteen. The sale of beer, under suitable restrictions, undoubtedly results in good rather than in evil to the troops at large, and may properly be looked upon as a safety valve for those accustomed to regard the use of a certain amount of liquor as both harmless and proper. Comparatively few men to-day become inebriates through a taste for alcohol acquired in the military service; and while there are a certain few individuals who may imbibe too much beer on pay day, they constitute a class which, in the absence of a mild beverage of this character, would probably resort to stronger—and frequently sophisticated—liquors outside the limits of the command. That beer-drinking, viewed in the abstract, is unproductive of good, will be admitted by all; that, when properly controlled, its sale in canteens, rather than its prohibition, redounds to the general health, morals, and military efficiency, few, if any, who are conversant with the subject will attempt to deny. It is certainly unfortunate that the temperance element in civil life, which is so constantly endeavoring to enact legislation against the sale of alcoholics of any character in the military service, cannot be brought to regard the matter from the practical rather than from the sentimental aspect, and thus assist in controlling and largely curtailing an evil which it is powerless to prevent, but which, if its efforts toward restrictive legislation should be successful, would undoubtedly be greatly increased.

It may here be remarked that the view is commonly entertained by the civilian class just mentioned that the soldier is a sinner above sinners and requires special legislative measures to safeguard him against his weakness—the fact being wholly ignored that the army is recruited from the general community, and merely reflects the qualities of the latter, whether they be good or bad. The recruit brings with him into the service the result of the moral moulding to which he has been subjected during childhood and youth in civil life, and does not change his nature or moral standards concerning alcoholics with the mere donning of the uniform. The vice of drunkenness is certainly no longer either directly initiated or aggravated as a result of military service, and if the opinions held by some are correct as to the moral conditions obtaining in the army, then its cause must be sought for within the social classes and the conditions of environment from which the human material composing the army is drawn. It is certain that there has been no more drunkenness to be found in the army—if indeed there has not been less—during the past few years than has occurred in the corresponding classes of civil life.

Venereal Disease.—Of all causes, venereal disease is the one which, in time of peace, brings the soldier oftenest to hospital and which most affects his efficiency—this being particularly the case in our own service.

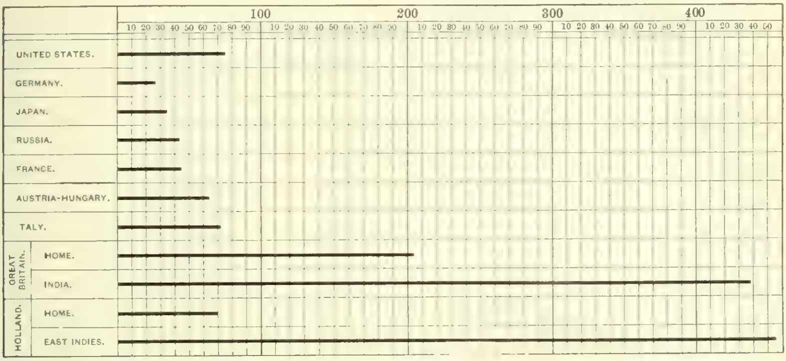

Fig. 1092.—Average Annual Admissions, per Thousand Strength, for all Venereal Diseases, in the More Important Armies of the World, for the Three Years 1890, 1891 and 1892.

The following table shows the ratio of admissions per thousand strength for all forms of venereal disease in the principal armies of the world, compiled from the most available and reliable data:

Year.	France.	Germany.	Austria-Hungary.	Russia.	Italy.	Holland home army.	Japan.	United States.	Great Britain. Home.	Great Britain. India.
1872	....	....	62	....	....	....	....	109.3	202.2	191.0
1873	....	....	56	....	....	....	...	101.7	167.6	181.6
1874*	...	38.4	53	....	....	....	..	92.5	145.7	207.5
1875	..	31.6	59	....	....	....	...	110.4	139.4	213.5
1876	57	28.8	65.8	....	....	....	....	107.6	146.5	203.5
1877	57.8	30	66.9	....	....	....	...	97.7	153.2	224.4
1878	59.7	36	75.4†	....	....	....	..	97.8	175.5	291.6
1879	63.7	38.5	81.4	....	....	....	.	95.1	179.5	253.3
1880	65.8	34.9	75.7	....	....	....	....	96.7	245.9	249
1881	60.6	39.2	79	....	....	....	....	91.8	245.5	259.6
1882	62	41	73.7	....	....	....	....	78.4	246	265.5
1883	58.9	38.2	73.3	....	....	....	....	76.6	260	271.3
1884	52.1	34.5	73.5	....	....	....	....	75	270.7	293.5
1885	50.7	32.6	69	....	....	....	....	79.6	275.4	342.6
1886	49.6	29.7	65.8	....	....	....	....	71.9	267.1	385.8
1887	51.6	28.6	64.4	....	47.5	...	39.3	74.37	252.9	361.4
1888	46.7	26.3	65.4	42.4	76.5‡	...	29.7	80.88	224.5	372.2
1889	45.8	26.7	65.3	40.7	66.6	....	24.7	84.66	212.1	481.5
1890	43.8	26.7	65.4	43	73.4	96	27.3	75.22	212.4	503.6
1891	43.7	27.2	63.7	41.5	71.5	60.4	37.5	72.46	197.4	400.7
1892	44	27.9	61.6	44.6	69	53.1	36	76.73	201.2	409.9
1893	42.8	....	64.5	43.1	93.3	45.8	....	73.38	194.6	466
1894	40.9	....	64.8	....	92	54.3	....	80.40	182.4	511.4
1895	....	....	....	....	84.8	48.1	....	73.70	173.8	522.3

* In the case of Germany, 1873–74, 1874–75, and so on.
† Bosnia and Herzegovina were occupied in this year.
‡ Compulsory examination of prostitutes abandoned.

Among European armies Germany has by far the lowest rate. Russia and France come next, then Austria-Hungary, then the home army of Holland, then Italy. No continental army included in the above comparison has so high a rate as that shown by the United States army—and with us, moreover, the actual prevalence of venereal disease, through its concealment to a considerable extent by the men, is probably greater than the returns indicate. The small amount of these diseases in the army of Japan is noticeable.

In all the above armies, with the exception of those of Great Britain and the United States, some special regulations are in force for preventing the spread of venereal disease. These generally consist of weekly or fortnightly examination of the men for the detection of venereal disease, non-commissioned officers and married men being in some services exempted, together with registration and periodical examination of all women ascertained to be leading a life of prostitution. In the Italian army, regulations of this latter kind were relaxed in 1888.

In the case of most of the above armies the comparison may be carried into further details as follows:

MEAN ANNUAL ADMISSION RATE PER 1,000 FOR THREE YEARS, 1890–92.

	Germany.	France.	Russia.	Italy.	Dutch Troops.		British Troops.		United States.
					Home.	East Indies.	Home.	India.	
Primary and secondary syphilis	5.5	9.0	13.1	13.9	14.8	47.0	101.7	175.4	16.83
All other venereal diseases	21.8	34.9	29.9	57.4	55.0	408.6	101.9	262.6	57.96

In these three years, then, the German army had scarcely more than one-thirty-second, and no European army had as much as one-eleventh, of the amount of syphilis which devastated the British troops in India. The Dutch troops in the East Indies, with an exceedingly high rate of venereal disease generally, did not suffer from syphilis one-third as much as did the white soldiers of the British Indian service; in which the rate has risen rapidly since the period included in the above comparison, while at the same time it has materially declined in the Dutch East Indies.

Syphilis.—Figures with regard to syphilis are of particular importance as directly bearing upon the military efficiency of an army. The disease, even at best, seriously undermines the constitution and renders the soldier at all times less resistant to invasion by acute disease and to its fatal termination. Even in many cases ultimately returned to duty, the men have frequently been in hospital for considerable periods and are prone to later manifestations from a temporarily latent infection. In such instances the state has not only paid the man for the time he was unfitted for duty, but receives back a doubtfully efficient soldier, extremely liable to break down under the fatigue and privations of field service.

The prevalence of constitutional syphilis in the United States army, during the past thirty years, has been as follows:

Year.	Admissions to hospital per 1,000 strength	Year.	Admissions to hospital per 1,000 strength.
1868	105.0	1883	35.6
1869	97	1884	29.8
1870	69.4	1885	24.8
1871	67.7	1886	22.3
1872	60.3	1887	22.9
1873	55.7	1888	22.2
1874	47.3	1889	22
1875	60	1890	19.7
1876	59.6	1891	14.7
1877	50	1892	16
1878	47.7	1893	13.6
1879	44.3	1894	14.1
1880	49.4	1895	11.1
1881	47.6	1896	10.9
1882	40.1	1897	12

During the year 1898 the admissions for this cause were only 10 per thousand.

As is seen by the above figures, syphilis has apparently diminished, during the past thirty years, to one-tenth of the amount existing in 1868. While it is probable that a certain proportion of this reduction is due to a more accurate differentiation between the hard and soft venereal sores, the fact nevertheless remains that the reduction in syphilis has been not only great but steadily progressive.

In the various armies on the European continent the tendency appears to be rather toward a reduction than an increase of syphilitic infection; but in the British army at home, and particularly among the British troops in India, a serious feature of recent years has been the disproportionately great increase in the amount of primary and secondary forms of this disease. This growth was not great prior to 1884, when the Contagious Diseases Act was revoked, but since that time the advance has been so extensive and rapid as to be appalling. In the following tables the rapid development of syphilitic disease among the British troops in India is well shown; though figures for primary syphilis cannot be given for the period prior to 1887, as the hard chancre was not required to be differentiated from the non-syphilitic sore until that year, and then only in part:

SECONDARY SYPHILIS, RATIO OF ADMISSION PER 1,000 STRENGTH.

Bengal figures		1877	22.1
1867	23.7	1878	22.1
1868	25.4	1879	24.1
1869	23	1880	23
1870	25	1881	23.1
1871	24.2	1882	23.2
1873	22.8	1883	23.5
All India		1884	24.4
1872	22.4	Mean for years 1872–84	23.3
1873	20.4	1885	28.7
1874	25.2	1886	33.3
1875	25.1	1887	29.4
1876	23.9		

Year.	Primary syphilis.	Secondary syphilis.	Year.	Primary syphilis.	Secondary syphilis.
1887	75.5	29.4	1892	102.6	57.8
1888	72.1	32.4	1893	129.3	61.6
1889	134.3	51.2	1894	173	74.6
1890	135.6	66.3	1895	174.1	84.9
1891	104	60			

In 1893, of the British troops in India, venereal disease caused 466 admissions per thousand strength. No less than 2,619 men, or equivalent to more than two regiments, remained constantly in hospital throughout the year from this cause. Each case required treatment, on an average, for thirty days, and the average rate of non-efficiency for each British soldier in India was twelve days lost. The admissions for syphilis alone were 275 per thousand. Of 70,642 British soldiers serving in India on the 15th of July, 1894, 19,892, or 28 per cent., had been admitted to hospital for syphilis since their arrival in India; and only 26,247 men, or 37 per cent., had never suffered in or out of India from any venereal disease. Of the 13,000 soldiers who returned to England from India in 1894, over 60 per cent. are reported as having suffered from some form of venereal disease. In 1895, an average of 45 men per thousand, or 3,200 of a total force of 71,031 British soldiers in India, were constantly in hospital for venereal disease. But these figures by no means represent the total amount of inefficiency due to this cause. Many cases of secondary syphilis, in the British service, have in the last few years been treated by hypodermic injection of mercury without admission to hospital, and do not, therefore, figure in the returns; while a large number of men who have been discharged from hospital as nominally cured are fit for service only under peace conditions. Among 5,822 men detailed for field service with the Chitral relief force, 462, or nearly 8 per cent., had to be rejected, prior to military operations, for exist-

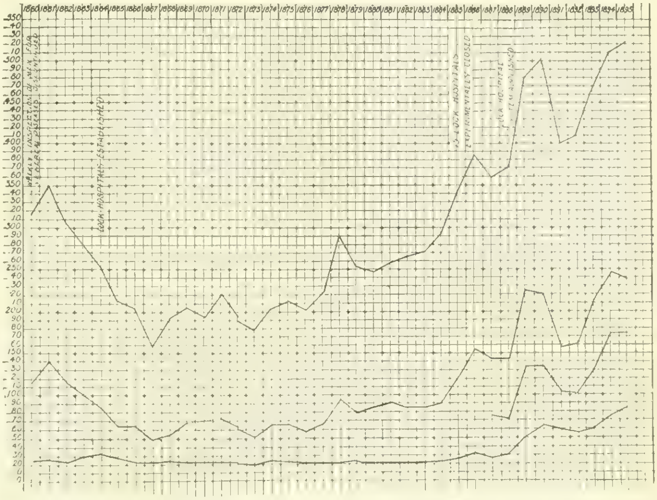

FIG. 1093. Chart Illustrating the Admissions for Venereal Diseases, per 1,000 Strength, among British Troops in India, 1860–95. 1, All venereal diseases; 2, all venereal ulcers, primary; 3, primary syphilis, proper (1887–95 only); 4, secondary syphilis. (From report of Royal Sanitary Commission.)

ing venereal infection; 279 more, or an additional 4.5 per cent., had subsequently to be transferred from the field hospitals to the base for the same cause. On a basis of 8 per cent. rejected before starting on field service, and 4.5 per cent. more subsequently invalided for disease contracted before crossing the frontier, 8,880 men out of the total British Indian force of 71,031 would have to be put down as useless, from this one cause, for field operations. The report of the Departmental Committee says: "In 1895 venereal disease attacked the British troops in India to an unprecedented extent. Out of the enormous total of 522 cases of venereal per thousand troops, syphilis contributed nearly one-half, *i.e.*, 259 cases per thousand, a figure many times greater than the highest of which we can find any record in the statistics of continental armies for recent years either at home or abroad. Venereal disease caused more than one-third the total amount of sickness from all causes, the constant disablement of 3,200 men out of a total force of 71,000 and a vast amount of partial disability and unfitness for any but routine duties." In the mountain campaign of 1897, it is stated that out of an actual strength of 16,600 British troops on active service, 492, or 3 per cent., were incapacitated during the campaign from venereal disease. The 16,600 troops in the field were drawn from a force of 21,439 men. Of these, 989 were rejected as unfit for active service on account of venereal disease. Hence 1,481, or nearly 7 per cent. of the total strength, were disqualified for service through this cause.

As illustrating the constantly increasing proportion of venereal diseases, among British troops in India, as compared with all affections of a non-venereal character, the following figures are of interest:

MEAN ADMISSION RATE FOR NON-VENEREAL DISEASES.

Year.	Per 1,000.	Ratio of venereal to non-venereal admission rate.	Year.	Per 1,000.	Ratio of venereal to non-venereal admission rate.
		Per cent.			Per cent.
Bengal:			India:		
1860-64..	1,606	18.2	1890....	1,016	49.5
India:			1891....	978	40.9
1872–76..	1,177	17	1892....	1,107	37
1887.....	1,009	35.8	1893....	949	49.1
1888.....	1,010	36.8	1894....	997	51.3
1889.....	1,017	47.3	1895....	940	55.5

In this service, also, the present greater virulence of venereal disease, as compared with former periods, is attested by a longer average duration of treatment and by an increase in the numbers of invalidings and deaths due to venereal disease, as shown in the following table:

Year.	Average duration of each case of venereal disease. Days.	Ratio of men discharged for venereal disease to total number discharged. Per cent.	Ratio of deaths due to syphilis to total deaths. Per cent.
1887........	25.95	3.0	0.1
1888........	25.68	7.7	.4
1889........	28.39	7.2	.5
1890........	29.07	6.3	.6
1891........	29.50	10.9	.3
1892........	29.01	9.	.8
1893........	29.82	3.7	.5
1894........	30.77	10.3	.4
1895.......	31.49	15.8	1.5

As showing the extraordinary prevalence of syphilis in the British army as a whole it is of interest to note that, according to Longuet, this disease, in 1888, was fifteen times more prevalent among British than among French soldiers; while for the year 1896 the number of constantly sick from this cause, per thousand strength, was 14.22 in the British service and only 1.29 in the United States army.

It is probable that there is less syphilis among the soldiers of the various European nations, excluding England, than exists among the unmarried male civilians of the same class, since those which appear to be severely infected with constitutional disease are promptly discharged from the military service.

In the United States service, gonorrhœa, in contradiction to syphilis, has been steadily on the increase for the past fifteen years; thus showing that there has been no improvement in the morals of the United States soldiers as regards chastity. In 1885, the admission rate for this cause was 37.76 per thousand, while in 1897 the rate was 56.21 per thousand. For the year 1896 the number constantly sick from this cause in the British service was 9.15, as compared with 3.22 in the United States army for the same period. In 1890 the admissions for gonorrhœa, per thousand strength, were 27.9 for the French army.

In the latter service, according to Marvaud, venereal disease of all varieties has steadily diminished, as follows:

Period.	Admissions per 1,000 strength.
1862–69	106
1872–79	74
1880–88	55
1889–90	45

Causes Affecting the Prevalence of Venereal Disease among Soldiers.—The influence exerted by race upon the prevalence of venereal disease is undoubtedly not sufficiently appreciated by medical officers. A marked difference in this respect exists even among the various armies of Europe, where similar measures of prophylaxis against venereal infections are in vogue; but it is when the rates for Asiatic forces are compared with those for white troops serving under the same conditions that the greatest difference is observed—this being particularly the case with reference to syphilis. It is undoubtedly true that this latter disease, introduced only comparatively recently among the white and negro races, commits far greater ravages among those in which it has not long prevailed than among peoples who have acquired a comparative immunity to the affection transmitted through a syphilized ancestry extending through scores of generations. It appears to be true, also, that certain races possess in large degree peculiar powers of resistance to gonorrhœal infection; a quality long since demonstrated to exist in certain individuals of even the most susceptible peoples. The following table, taken from the report of the commission investigating the prevalence of venereal diseases among the British troops in India, well shows the great difference in the admission rates for Europeans and Asiatics in respect to venereal disease:

RATIO PER 1,000 STRENGTH.

Year.	DUTCH ARMY IN THE EAST INDIES.				ENGLISH ARMY IN INDIA.			
	European Troops.		Asiatic Troops.		British Troops.		Native Troops.	
	Syphilis.	All venereal diseases.	Syphilis.	All venereal diseases.	Syphilis.	All venereal diseases.	Syphilis.	All venereal diseases.
1890	53.9	483.9	11.0	248.0	201.9	503.6	18.2	41.1
1891	43	442	11.6	243.6	164	400.7	16.3	37.9
1892	44	440.9	9.7	223.5	160.4	409.9	17.1	39.6
1893	40	370	8	218	190.9	466.	17.9	36.4
1894	37	416	7.8	191.8	247.6	511.4	17.7	32.3
Mean for 5 years	43.6	424.7	9.6	225	195	458.3	17.4	37.5

From this it is seen that, in the Dutch East Indies, Asiatic troops suffer from all venereal diseases slightly more than one-half as much, and from syphilis but about one-fourth as much, as do Europeans. In the British forces in India the native troops do not suffer from venereal disease one-twelfth as much, nor from syphilis one-eleventh as much, as the white troops. It is probable that in India caste feeling helps to deter the native soldier from consorting with the lowest and most dangerous class of prostitutes, but his great freedom from venereal disease can be explained only on the ground of racial insusceptibility. It is of interest to note that while the admission rate for British troops in India has more than doubled since 1881, among the native troops there has been no appreciable increase. An inference which may be legitimately drawn from this fact is that venereal disease has not increased to any remarkable extent among the loose women of the country generally, but that among the class with whom the British soldier associates there has been an increase out of all proportion to their numbers directly as a result of such relations; both the native women and the British soldiers presenting rates far in excess of their racial normals. As between whites and negroes the greater resistance to venereal infection lies with the former, probably through a longer exposure to the processes of immunization through heredity. Comparative figures for these two classes in the United States service, for all venereal diseases, are as follows:

Year.	Admission rate per 1,000 strength. Whites.	Admission rate per 1,000 strength. Colored.	Admissions per 1,000 strength for entire army.
1884	75.00	101.00	78.00
1885	80.00	76.00	80.00
1886	....	......	74.37
1887	72.13	95.98	74.37
1888	78.08	98.51	80.07
1889	84.86	82.75	84 66
1890	72.02	105.39	75.21
1891	70.64	80.18	72.46 *
1892	75.71	86.94	76.72 *
1893	74.94	49.00	73.08 *
1894	82.21	47.46	80.43 *
1895	75.57	52.26	73.72
1896	80.04	56.53	78.08
1897	81.80	114.60	84.59
Decade 1886–95	75.89	78.48	76.32 *

* Including Indian troops.

No satisfactory explanation of the sudden and marked reduction of the admission rates for the colored troops for the years 1893–96 can be offered. The experience of the British in the West Indies shows a higher percentage of venereal disease among colored troops than among white soldiers, syphilis being more than twice as common among the former as among the latter.

Another point well worthy of careful consideration is found in the fact that venereal infection, particularly of a syphilitic nature, appears to take place more certainly and to assume a much more severe character when relations are entered into between individuals of different racial characteristics than when both are of the same nationality; the aliens suffering in this respect to a greater degree than the resident population. It would almost seem as if there were localized varieties of venereal disease the product of special environment, to one of which a race might be relatively insusceptible, although at the same time falling an easy prey to the allied diseases prevailing among peoples of other countries. Troops quartered among an alien but not entirely hostile population almost invariably suffer worse in respect to venereal disease than those at home. In the Austrian army a large increase in such diseases followed the occupation of Bosnia-Herzegovina in 1878; the French troops in Algiers are more affected with venereal disease than those in France, and the same is true to a marked degree in the case of the British troops in India and those of the Dutch in Java. In speaking of the native troops stationed in Bengal, it has been said with respect to venereal diseases that the "Gurkhas, being foreigners, have higher rates than other native troops." These conditions, however, do not obtain when a command is moving or during campaign. The following tables well illustrate the points just advanced:

AMOUNT OF VENEREAL DISEASE AMONG FRENCH TROOPS IN FRANCE AND IN ALGERIA, COMPARED. (Admissions per 1,000 strength.)

Year.	TROOPS IN FRANCE.				FRENCH TROOPS IN ALGERIA.			
	Syphilis.	Chancre.	Gonorrhœa, etc.	Total.	Syphilis.	Chancre.	Gonorrhœa, etc.	Total.
1892	8.3	5.6	27.4	41.3	15.0	11.9	28.6	55.5
1893	8.4	5.8	25.3	39.5	15.0	12.1	32.5	60.6
1894	7.4	5.2	23.5	36.1	13.2	11.4	26.6	51.2

ADMISSIONS PER 1,000 STRENGTH, FOR THE DECADE 1887–96, FOR BRITISH TROOPS IN INDIA AND AT HOME STATIONS.

Disease.	British army on the home stations.	British army in India.
Primary syphilis	59.2	127.5
Secondary syphilis	35.9	62.2
Gonorrhœa	86.2	176.3

AMOUNT OF VENEREAL DISEASE AMONG THE DUTCH TROOPS AT HOME AND IN THE EAST INDIES COMPARED. (Admissions per 1,000 strength.)

Year.	Troops at Home.			Abroad.					
				European Troops.			Asiatic. Troops.		
	Syphilis.	Other venereal diseases.	Total.	Syphilis.	Other venereal diseases.	Total.	Syphilis.	Other venereal diseases.	Total.
1885	No returns for these years.			58.9	335.0	393.9	15.7	188.0	203.7
1886				60	411	471	15	143	158
1887				61.8	447.7	509.5	16.3	221	237.3
1888				53	384	437	12.9	203	215.9
1889				49.8	417.6	467.4	12.6	254	266.6
1890	13	83	96	53.9	430	483.9	11	237	248
1891	18	42.4	60.4	43	399	442	11.6	232	243.6
1892	13.4	39.7	53.1	44	396.9	440.9	9.7	213.8	223.5
1893	10.8	35	45.8	40	330	370	8	210	218
1894	13.3	41	54.3	37	379	416	7.8	184	191.8

Climate also appears to influence the prevalence of venereal disease, as well as its intensity and character; a tropical climate appearing to lower the vital resistance as regards invasion by venereal infection, to induce disease of unusually severe type, and to cause, in syphilis, the determination of superficial rather than deep-seated lesions. The amount of venereal disease also bears a close relation to the age of the soldiers; young men, and particularly young recruits, being especially liable to such disease. The proportion of married men among the troops naturally exerts a marked influence on the occurrence of such affections; figures for the British army in India, for the years 1867–72, showing that the percentage of admissions for venereal disease among married men was one-fiftieth of the percentage for the unmarried. As might have been expected, recent investigations in the British service in India show that cases of venereal disease are much less numerous among abstainers than among those habituated to the use of alcoholics. In the French army, during the year 1887, it was found that the amount of venereal disease for each garrison depended directly upon the amount of clandestine prostitution; the prevalence of these affections varying directly with the rigor with which surveillance of prostitutes is maintained. According to von Tophy, the relative venereal morbidity in the armies of Austria, Germany, France and Italy bears a close relationship to the prevalence of this class of diseases among the civilians in the district in which they are quartered, and hence all measures for the restriction of the disease should primarily be applied to the civil population. The amount of venereal disease also depends, according to Jeannel, upon the virulence of the type of the affection as found in foreign countries, and upon the facility of communication with the civil classes.

Measures Looking to the Diminution of Venereal Disease among Troops.—Since no systematic attempt has been officially made for this end, within the limits of the United States, through the control of prostitution in its relations to our military service—save at Memphis and Nashville, during the Civil War,—it is necessary to turn for data on this subject to the ample experience of other nations. In our small army, containing, as it has in the past, a large proportion of married soldiers and scattered in small detachments over a vast territory, the necessity for the restriction of venereal disease among troops through the control of prostitution has not been markedly manifest; and the execution of such restrictive measures would indeed have been impracticable at home stations. With the altered conditions and changed moral and social environment which have, however, resulted from recent acquisition of foreign territory and contact with alien races, the subject at once assumes a vast importance, believing, as we must, that the experience of the United States as regards the occurrence of venereal disease among troops will not be greatly different in this respect from that of England, France, Holland, and other countries holding tropical colonies. That we may profit in the future from their mistakes of the past, and treat this matter forcefully, practically and with an absence of sentiment, is much to be desired, but, in view of the varying political conditions controlling the policy of a republican form of government, this is a result which is scarcely to be anticipated.

On examining the figures given in the British Army Medical Department Report for 1883, as illustrating the influence of restrictive legislation in England upon the prevalence of venereal disease, the fact which chiefly attracts the attention is the enormous difference between the number of admissions for primary syphilis in the districts in which prostitution was regulated as compared with the admissions in the stations not under the Contagious Diseases act. In the former the average annual rate for a period of thirteen years was 50 per thousand; in the latter the admission rate was 118 per thousand.

The following table gives the total admissions for primary syphilis and the average strength:

AVERAGE STRENGTH AND TOTAL ADMISSIONS FOR PRIMARY SYPHILIS, 1870–82.

Fourteen stations under the act.		Fourteen stations not under the act.	
Average strength....	47,394	Average strength.....	19,218
Total admissions	31,105	Total admissions	29,582

If these figures be compared, it is observed that if in the subjected stations the ratio of admissions had been the same as for those not under the act, the total admissions for primary syphilis would have been 72,952. It is thus obvious that 41,848 men were prevented from contracting the worst form of venereal disease, in this one group of stations, owing to the enforcement of the provisions of the Contagious Diseases act. The number constantly in hospital for primary syphilis was only 3.97 per thousand in the group under the act, while in the group in which regulations were not in force it was 9.16 per thousand. The actual number constantly in hospital in the subjected group was 188, but if it were in the same proportion as in the group not under the act, the amount would have been 434; it is therefore evident that there was a daily saving of 246 men from being sick in hospital with primary syphilis. In May, 1883, the act was practically done away with, the compulsory examination of prostitutes having then ceased; and the following tables are of interest as showing the disastrous results of interfering with such an essential regulation:

CONSTANTLY IN HOSPITAL PER 1,000 STRENGTH, PRIMARY SYPHILIS.

Year or Period.	Group of stations under the act.	Group of stations not under the act.
1870–82	3.97	9.16
1883	8.66 Act modified	15.81
1884	12.41	14.01

ADMISSIONS TO HOSPITAL PER 1,000 STRENGTH, PRIMARY SYPHILIS.

Year or Period.	Group of stations under the act.	Group of stations not under the act.
1870–82	50	118
1883	110 Act modified	188
1884	138	160

Browning has compared the admissions for primary syphilis, in the year 1875, at Chatham-Sheerness and London, one subjected to, and the other not under, the act; the average strength of each being about 4,000 men and the places not far apart. For the former station the admissions for this cause were only 17 per thousand for the period mentioned, while for London the admissions were 187 per thousand. Before the act came into force the admissions at Chatham-Sheerness were 94 per thousand (average of 1860–66). From 1867 to 1882 the rate was only 49 per thousand. On abolishing the compulsory examination of prostitutes the ratio for primary syphilis rose, in 1884, to 141 per thousand. The average for London for 1867 to 1882, not under the act, was 181 per thousand.

The effect of the Contagious Diseases act in the United Kingdom in the number of admissions for gonorrhœa was not so marked as in the case of primary syphilis; the ratio of admissions for this cause was 84 per thousand in the subjected group, while in the stations not under the act the ratio was 105 per thousand. It is computed, however, that the act prevented about 12,000 cases of gonorrhœa during the period 1870–82 at the fourteen stations where the regulations were in force.

Previous to 1885, in the British service in India, lock hospitals had been established for the treatment of women suffering from venereal diseases. All prostitutes living in cantonments were registered and subject to medical examination. In many cases special quarters were allotted to them in regimental or cantonment bazaars, and women evading the rules were subject to ejectment from cantonments. In that year the Indian Government decided that a certain number of these lock hospitals should be closed, with a view to a comparison being made of the results at these stations and at protected stations. In 1887 the results obtained showed that there had been a marked and progressive increase of venereal disease at stations in which the lock hospitals had been closed, and the percentage of disease compared most unfavorably with the percentages at the stations at which these institutions had been maintained. The hospitals previously closed were directed to be re-opened, but in 1888 all control over prostitution in India was done away with by an act of Parliament. Since 1887, the last full year of the protective system, there has been an advance of primary venereal disease of 137 per cent., and of secondary disease of 188 per cent.; a progressive severity of cases expressed by an average stay in hospital of 31.5 days in 1895 as compared with 26 in 1887, and a temporary inefficiency of the force exemplified by the fact that in 1895, out of 68,331 men in cantonment 36,681 were in hospital for the above average period, of whom 22,702 were suffering from syphilis. The number constantly inefficient from venereal disease was 3,164. The invaliding from this cause advanced from 1.13 per cent. under restrictive measures to 5 per cent. in the statistics for 1895. In regard to the prevalence of venereal disease in India in 1894–95, the army sanitary commission wrote: “The results of experience in India since 1885, when a number of lock hospitals were closed, and in subsequent years when all restrictive measures were gradually removed, show that a progressive increase of venereal diseases has taken place among the British troops serving in India; and there is, unfortunately, no assurance that this increase has reached its limits.”

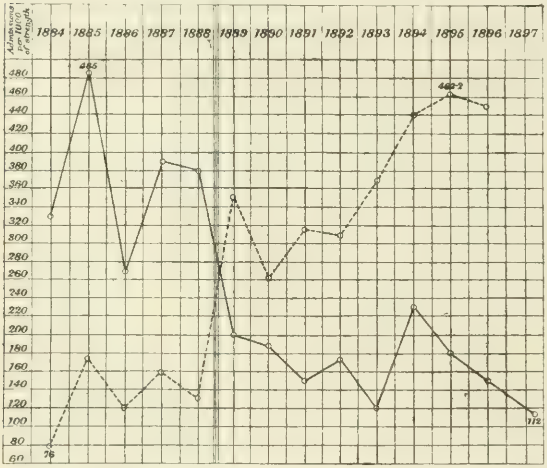

FIG. 1094.—Chart Showing the Influence of Laws Regulating Prostitution in the Rohilkhand District, India, and Cape Town, South Africa, upon the Admissions, per Thousand Strength, for Primary and Secondary Syphilis, from the British Troops Stationed at those Points. Black line, Cape Town; dotted line, Rohilkhand. Cape Town, without regulations, 1884–88, average admissions, 371; Rohilkhand, without regulations, 1889–97, average admissions, 370; Rohilkhand, with regulations, 1884–88, average admissions, 132; Cape Town, with regulations, 1889–97, average admissions, 168. (After Browning.)

In the year 1889 a Contagious Diseases act was brought into force at Cape Town, South Africa, and in the same year all regulations for checking the spread of venereal disease were done away with in India; so, for a period of eight years it is possible to compare India, minus regulations, with Cape Town and an act in force. For the five years previous to the act coming into force at Cape Town, the average admissions for primary and secondary syphilis were 371 per thousand of strength. The Rohilkhand district of India, for the years 1889–96, had just the same proportion of admissions, viz., 370 per thousand, both stations not being under a Contagious Diseases act.

For the nine years (1889–97) during which the act was in force at Cape Town, the admissions gave an average of 178 per thousand; Rohilkhand, for a like number of years (1880–88), having nearly the same number of admissions, 134 per thousand, both stations being under a Contagious Diseases act. The accompanying chart graphically shows the influence of the acts upon the admissions for syphilis in these two stations; the heavy vertical lines marking the abolition of all restrictions in India, this being followed by an immediate and extraordinary rise; and also showing the point at which unrestricted prostitution in Cape Town came under official control, a remarkable and permanent decrease resulting. To such a convincing argument of the value of controlled prostitution it would be almost superfluous to add.

Browning states that previous to the Contagious Diseases act coming into force at Cape Town, venereal diseases of all kinds were rampant, and the admissions to the military hospital from this cause appalling, they having reached 828 per thousand of strength. At no other region where British troops were stationed did the admissions reach such proportions. On comparing the admissions to hospital for venereal diseases for the quinquennial period before the act, and the years following the act, a vast difference in the total sick with venereal disease was apparent. The average for all forms of venereal disease for the years 1884–88 was 674 per thousand, while the average for the years 1889–97 was only 349. This was not a gradual fall which might be accounted for by an improvement in morals, but a sudden descent from 828 per thousand in 1888 to 347 per thousand in 1889, and the rate is still decreasing. In 1896 it was only 216 per thousand.

In comparing the figures for all forms of venereal disease at Cape Town, it appears that not only has the number of venereal cases fallen since the act came into force, but of late years a large proportion of such affections consisted of milder complaints. These, before the act, constituted 34 per cent. of the total; for the eight years subsequent to the act they averaged 49 per cent. It is interesting to notice the great fall in the admissions for constitutional syphilis. In 1888 the ratio for this disease was 209 per thousand, while in 1896 it was only 27 per thousand. The average rate for the quinquennial period 1884–88 was 137 per thousand, falling to 51 per thousand for the period 1889–97. The disease was rapidly increasing when no regulations were in force, but twelve months after the act was promulgated the number of attacks fell to what must be considered a satisfactory ratio under the circumstances, and, with the exception of the years 1892, 1894, and 1895, the figures were under 50 per thousand.

That the supervision and control of prostitution produce a beneficial effect on the general health of the troops at Cape Town is evident from comparing the total admissions per thousand of strength for all forms of disease, other than venereal disease, before the act, with the admissions after the act. For the five years previous to the act, the average annual rate for diseases other than venereal affections was 553 per thousand of strength, while for the years after the act (1889–97) the admissions were 502 per thousand, a fall of about 10 per cent.

Browning concludes that the Contagious Diseases act of the Cape of Good Hope has "been the means of preventing thousands of soldiers in the garrison at Cape Town from being incapacitated by venereal diseases," and that "the men who still contract such complaints suffer from a milder form than existed prior to the act coming into force." He believes that "the act is a humane one, relieving the sufferings of hundreds of prostitutes and also alleviating the distress of women who, though not strumpets, contract venereal disease."

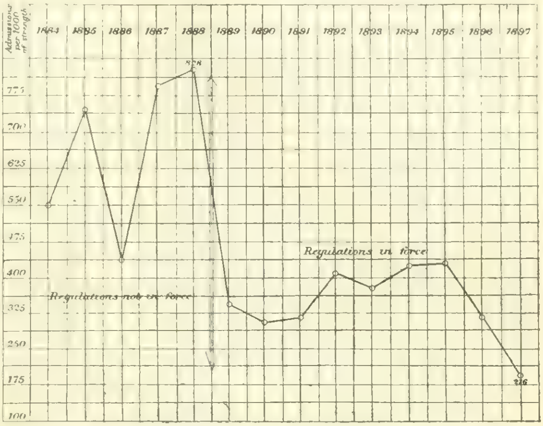

FIG. 1095. Admissions for All Venereal Diseases, per Thousand Strength, among the British Troops at Cape Town, Before and After the Regulation and Official Control of Prostitution. (After Browning.)

In the province of Pinar del Rio, Cuba, during its recent occupation by United States troops, the following order was published and enforced: "Clandestine prostitution will not be tolerated. Prostitutes shall be registered. They shall live in such locations as are indicated. Each prostitute shall have a book. In this her name, age, nationality, and address shall be recorded. She shall be examined at least once a week by a physician, and the examining physician shall sign the book. This examination shall be good only for one week. Any prostitute doing business when her book is not signed to date shall be punished. She shall not change her residence without the permission of the sanitary inspector. The proprietors of houses of prostitution will be held accountable for the condition of the houses and of the inmates, also for the orderly conduct of those living in or visiting such houses. No liquor shall be sold, given away, or drunk in houses of prostitution. Each prostitute will be required to provide the means necessary for securing her own and her visitors' cleanliness. Cases of venereal disease must be at once reported to the health inspector. When venereal disease is traced to any particular person, such person will be subjected to punishment." As to the results which followed the enforcement of this order, Kneedler writes: "In connection with the matter of regulated prostitution, this command has been in Cuba three months and numbers three thousand men. These men have free access to the towns. I have not been able to find more than nine men who have contracted venereal disease in the Department of Pinar del Rio."

In the report concerning the sickness among the British troops composing the Dongola expeditionary force, in 1896, the chief medical officer says: "On first arriving at Wady Halfa there was some trouble found in checking clandestine prostitution. There were a large number of native women who were living just outside the English lines, and it was from these women that the men contracted disease. There was a licensed brothel under supervision in the native town of Wady Halfa, and the women there were periodically examined. Very few cases of disease were contracted there. Stringent police precautions were taken, and a military patrol was placed outside the camp to prevent women from coming near, and this answered so effectively that after a few weeks the nuisance was almost stopped and there were hardly any admissions afterward for venereal."

For the period 1863–65 the Italian army had an admission rate for venereal disease of 120 per thousand; this falling in 1874–76, as the result of sanitary inspection and careful control of prostitution, to 66 per thousand.

Such facts as are given above may be greatly multiplied, and there can be no doubt that the intelligent regulation of prostitution results in a great decrease in venereal disease; this is to be accomplished by a system including careful registration and surveillance and frequent official medical inspection. The latter requirement is of the greatest importance, a fact of which the British Sanitary Commission in India was fully convinced when it reported: "We are satisfied from the evidence that the frequent examination of women is the most efficacious method of controlling the disease." These examinations should be made in private, and only in the presence of official examiners. The latter may be females who have been sufficiently trained for the intelligent discharge of this duty. Military garrisons attract to their vicinity lewd women of the lowest character, and largely subjects of venereal affections. Such being the case, great care should be taken to prevent loitering or importuning by this class or by their male associates within the limits of the command. Particularly in the tropics it is desirable that no females should be employed in, or in the immediate vicinity of, the barracks, since there is evidence that such women are frequently the source of aggravated forms of venereal disease. Clandestine prostitution should be prevented as furnishing a high rate of venereal disease. Colin noted that of 32 syphilitic French soldiers, 14 were infected by public prostitutes and 18 by women employed in so-called wine-shops. All public prostitutes should be segregated within well-defined limits as regards residence and public solicitation severely punished. Brief printed instructions should be furnished these women as to the dangers and prevalence of venereal disease and the importance of cleanliness as a measure of prophylaxis. Next to medical inspection, it is probable that care in maintaining cleanliness of the person is the most important factor in the prevention of venereal disease; it having been experimentally determined that infection from the non-syphilitic venereal sore may usually be prevented by a thorough cleansing of the parts with soap and water if done within ten minutes from the time of exposure. When diseased, such women should be at once isolated in a proper institution. Apart from the great importance of such action upon the general welfare, it is merely a matter of humanity to these unfortunates that they should have the benefits of medical treatment, with rest and care in hospital, until they are cured. Obedience to these regulations should be enforced by police authority, and public exposure, as far as the occurrence of venereal disease is concerned, should, as far as possible, be prevented. It should not be forgotten that when official control becomes too rigorous the number of avowed public women undergoes diminution, while clandestine prostitution increases.

The large amount of venereal disease occurring among troops—a condition entirely preventable and dependent upon vicious indulgences on the part of the soldier—has led many to suggest the institution of measures calculated to prevent its occurrence through the imposition of penalties upon those offending in this respect. It has been suggested that those incapacitated for duty from this cause be deprived of their pay while rendering no service to the government; that their privileges be restricted, or that confinement be imposed. All these plans are, however, readily defeated by the concealment of the disease; and the proper imposition of punishment for this cause could be made only with the assistance of a careful system of inspection. In the French service a month's imprisonment was at one time imposed upon every venereal case after discharge from hospital, but this led the men to conceal their diseased condition from the medical officers and place themselves in the hands of empirics, and the order was revoked. It is certainly subversive of discipline and unjust to the more continent class of men that they are obliged to perform the extra duty which results from the entrance into hospital, as a result of their own misconduct, of those by whom such work should rightfully have been done. Such a condition of affairs obviously puts a premium upon participation in vice, and it is much to be regretted that no satisfactory method for its punishment has as yet been devised. Where measures for the control of prostitution can be carried out, the soldiers affected with venereal disease should be required to state where and from whom it was contracted, with a view to the proper segregation and treatment of the women indicated. In the British service, however, during the existence of the cantonment laws, Welch states that some difficulty was experienced, in the attempt to identify the source of venereal infection, through the unwillingness of the soldiers to expose their co-partners in vice.

Many soldiers affected with venereal disease hesitate to declare its existence through the official publicity necessarily given to all cases, and through reluctance to have their names entered upon the records in connection with diseases of this character. As a result of such action the condition is, in many instances, aggravated either by being left without treatment or by the employment of patent medicines or unskilled advisers. Where venereal disease is concealed, the offender, if detected, should be severely punished; and where such practice is general the system of weekly inspection, as is customary in England and on the Continent, may have to be employed. This, in fact, has lately been carried out among certain of our regiments in the tropics. It should be thoroughly understood by the men that it is greatly to their interest, in the way of cure, to declare the existence of such a disease as soon as its appearance is noted. To further assist in the accomplishment of this object, it should be required that all non-commissioned officers knowing of the existence of cases of venereal disease in their troop or company should be held responsible for the prompt appearance of the sick men before a medical officer.

It would certainly be of advantage to the military service if a short series of lectures by medical officers were required to be delivered annually for the purpose of acquainting soldiers with the grave and far-reaching consequences that are likely to result from immoral conduct, particularly from clandestine prostitution; the importance of early treatment and the dangers of concealment; the intractable character of syphilis and the necessity for prolonged medication; the dangers resulting to the healthy from the presence of concealed venereal disease in barracks. Such lectures would be of special value at recruiting depots. Chastity should be inculcated. The common idea that celibacy increases sickness and mortality should not be encouraged, since although many single men renounce marriage because of bad health or disease, this is a cause not met with in the army, where there is an enforced celibacy analogous to that of priests, who, although single, live as long as married men.

Insanity and Suicide.—These are best discussed in this connection, since they are largely dependent upon the personal habits of the soldier, particularly in relation to alcoholism.

Mental diseases have undergone a considerable diminution in our service during the past few years, this undoubtedly resulting from the greater provision officially made for the intellectual needs and recreation of the soldier, together with the withdrawal of troops from small isolated posts and their concentration near large centres of population. The following figures show the rates for this cause for a period of thirty years:

Year.	Admissions per 1,000 strength.	Year.	Admissions per 1,000 strength.	Year.	Admissions per 1,000 strength.
1868......	1.7	1878.....	1.5	1888.....	1.7
1869......	1.5	1879.....	1.9	1889.....	1.3
1870......	2.1	1880.....	2.1	1890.....	1.3
1871.....	2.0	1881.....	2.5	1891.....	1.5
1872.....	2.4	1882.....	2.8	1892.....	1.9
1873......	2.2	1883.....	3.0	1893.....	1.3
1874......	1.8	1884.....	2.1	1894.....	.9
1875.....	2.2	1885.....	1.4	1895.....	.7
1876......	1.4	1886.....	1.4	1896.....	.8
1877......	1.6	1887.....	1.9	1897.....	.8

In contrast with the conditions prevailing in our service, as shown above, insanity would seem to be steadily on the increase in the French army. The figures given below refer to troops on home service and in Algeria, as sanitary statistics are not published regarding the garrisons at various other colonial stations:

Year.	Number of men invalided for mental alienation.	Year.	Number of men invalided for mental alienation.
1877.........	62	1884...........	73
1878...........	94	1885...........	120
1879............	77	1886...........	112
1880...........	63	1887...........	130
1881...........	82	1888...........	150
1882..........	81	1889...........	158
1883..........	64	1890...........	192

In the British army the rates for mental disease for the ten years 1887–96 are given as follows:

Station.	Admissions per 1,000 strength.	Station.	Admissions per 1,000 strength.
England	1.2	Bermuda	1.5
Scotland	1.8	West Indies	.7
Ireland	1.6	Ceylon	1.3
Gibraltar	1.	China	1.2
Malta	1.7	Straits Settlements....	1.5
Canada	.8	India..................	1.7

From the above figures it is seen that tropical service, contrary to what might be expected, does not apparently increase the liability to insanity.

The military spirit, which naturally cultivates indifference to life, is undoubtedly favorable to self-destruction, and does much to raise the rates for suicide in the military service above those prevailing in civil life. In addition to this feeling the soldier, constantly under the control of others, separated from home and friends and often occupying isolated and lonely stations, is more prone to melancholia and mental depression and the tendency toward suicide occurring therefrom. In the United States service, after the Civil War, the rate for suicide had increased greatly until within the last three years, when there was a sudden and great diminution. For various years the rates have been as follows:

Year.	Suicides per 1,000 strength.	Year.	Suicides per 1,000 strength.
1868	0.44	1889	0.83
1872	.51	1894	.79
1878	.63	1896	.43
1883	1.10	1897	.39

In 1898, a year of war, the rate greatly diminished, being only .04 per thousand strength. The suicides for the seven years 1887–93 inclusive amounted to a total of 134 cases: officers 7, and enlisted men 127. These were divided according to the branch of the service as follows:

Infantry	64
Cavalry	28
Artillery	15
Ordinance	5
Engineers	2
Medical and Hospital Corps	7
All others	13

Of these, 51 were under 30 years of age, 56 were between 30 and 40, and 27 were over 40. The methods of self-destruction employed were:

Gunshot	97
Poison	26
Drowning	4
Throat-cutting	3
Severing radial artery	1
Suffocation	1
Strangulation	1
Crushing by railroad train	1

In 37 instances the causes of the suicide were undetermined. In the others the causes were reported to be as follows:

Alcoholism	42
Despondency	12
Insanity	10
Love troubles	6
Temporary mental aberration	5
Fear of court martial	5
Domestic troubles	3
Fear of results of syphilis	2
Losses by gambling	2
Charge of theft	2
Jealousy	2
Homesickness	1
Nervous depression	1
Failure to obtain promotion	1
Tired of living	1
Distaste for service	1

For the four years 1894–97, of the 58 suicides committed, only 3 occurred in the first year of enlistment; thus corroborating the general impression that self-destruction prevails chiefly among old soldiers. It will be observed that in our army, recruited by voluntary enlistment and with a short term of service, the suicides from dislike of the service or other reasons depending upon a military life are much less frequent than in foreign armies maintained by compulsory enrolment.

According to Millard, the rate per thousand for suicide for the entire British army during the period 1852–56 was .155; for the period 1859–66 the rate was .26; in 1866–70 it was .443. In 1873 it had fallen to .25. For the British army on the home stations the rate was .23 in 1897, .21 in 1896, and .20 as an average for the preceding ten years. For stations outside the United Kingdom these latter rates were practically doubled. In most cases the causes of suicide were stated to be unknown. In others, they were variously reported as hypochondriasis, disappointment in love, excessive drinking, dislike of the service, fear of punishment, insanity following diseases like malaria and typhoid fever, and "temporary insanity." The chief methods selected for self-destruction were, in order of preference, shooting, hanging, drowning and throat-cutting.

In the French army serving at the home stations, the rate for suicide, as given by Viry, was .47 for the period 1862–69, and .29 for the years 1872–90. In a study of 69 cases, 9 of which occurred in sergeants, Arnould divided the causes as follows:

Fear of punishment	21
Mental alienation from disease	13
Unknown	12
Disappointment in love	9
Hypochondriasis	8
Alcoholism	6

Viry states that only one-sixteenth of the suicides among French soldiers are attributed to dislike of the service; the greater number being due to the fear of punishment, brought about by neglect of duty and not by the severity of discipline. In Algeria and Tunis, for the period 1872–90, the suicide rate was .68 per thousand.

In the Prussian army, 1829–38, Baudin states that the suicides averaged .50 per thousand strength. From 1846 to 1863 the rate was .46; from 1867 to 1872 it was .60. For the entire German army, 1873–78, the rate was .61, and from 1878 to 1888 it was .67 per thousand. The Saxon army corps is said to have had an unusually high rate, the suicides for a long time averaging .92. The rate for suicides in the German army is nearly twice as great as that for the French service. In 1889–90 the proportional number of suicides, calculated for each thousand deaths from all causes, was as follows:

Under one year of service	87.7
From one to two years' service	30.9
From two to three years' service	25.9
From three to four years' service	8.6
Four years' service and upward	38.8

The causes of suicide may be roughly divided into one-third due to fear of punishment, one-half to mental diseases, and the remainder divided into disappointment from various causes and dislike of the service.

In the Austrian army the rate for self-destruction is extremely high, having been .97 in 1870 and .81 in 1873. For the former year, suicide was relatively four times more frequent in non-commissioned officers than in privates. Of late the mortality from suicide represents 1.5 per cent. of the general mortality, and this rate appears to be increasing. As in the German army, more than half the suicides occur during the first year of service; and mutilations of the index finger, middle finger and thumb of the right hand—to incapacitate for military service—are common. One-third of the suicides are ascribed to dislike for the service, one-third to fear of punishment and one-third to melancholia. About 70 per cent. are accomplished by shooting and 20 per cent. by hanging.

In the Italian army, in 1887, the rate for suicide, per thousand strength, was .30. In 1888 it was .45, and in 1889 it was .38. Three-fourths of the cases are officially attributed to causes foreign to the military service.

DISEASES INDUCED BY EXPOSURE

BRONCHITIS.—This affection, in our army, is one of the most frequent causes whereby soldiers are rendered temporarily incapacitated for duty. Its mortality in young men of the military age, when occurring idiopathically, is, however, small. In the United States service the admissions for bronchitis, since the year 1860, have undergone a certain decrease during the period of peace, being as follows:

Period.	Admissions per 1,000 strength.
1861–66 (Civil War)	92.94
1868–84	77.73
1885–94	68.67
1895–98	75.48
Year 1897	59.72
Year 1898 (war with Spain)	100.65

Bronchitis may be brought about by a great variety of causes. There are those who regard it as largely due to the invasion of some specific micro-organism as yet undetermined; and any irritant gas or dust may produce it. In the military service, however, the evidence that an important part in its origination is played by exposure and cold, particularly the latter, is conclusive. Reports for our army have for many years shown its greatest prevalence to occur in the more northern military departments and posts; and the remarkable influence of cold weather in inducing this disease, as determined by months, is well shown in the accompanying diagram. It would seem to be abundantly demonstrated that, for our army, idiopathic bronchitis chiefly results from exposure to cold; this interrupting the eliminative functions of the skin, whereby an increased duty is thrown on the pulmonary mucous membrane, thus inducing internal congestion. This hypothesis largely explains the commonly observed fact that outbreaks of considerable magnitude not infrequently occur among troops who are naturally exposed to the same meteorological and environmental conditions. Age is a factor of great importance in the occurrence of the disease, very young and very old soldiers being particularly liable to it. For the period 1890–96, figures showing the distribution of bronchitis, according to age, are as follows:

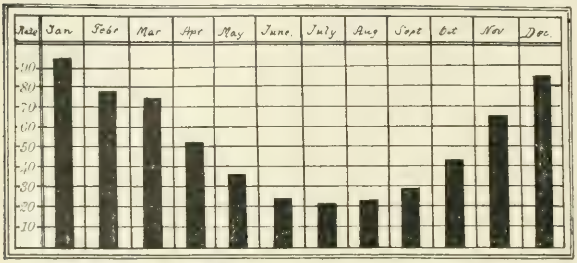

FIG. 1096.—Distribution of Cases of Bronchitis in the United States Army, by Months, per Thousand Strength, for the Decade 1875–1884.

Age.	Admissions per 1,000 of each class.
19 years and under	132.08
20 to 24	83.70
25 to 29	60.66
30 to 34	57.15
35 to 39	53.98
40 to 44	60.52
45 to 49	61.39
50 to 54	70.75
55 to 59	88.60

The greater exposure incident to mounted service explains the higher rates, for the above period, given by cavalry, 76.08 per thousand strength, as compared with infantry, 63.18 per thousand strength. The same condition explains the greater frequency of this affection among troops in the field as compared with those in garrison; the proportion of cases during the year of war (1898) being almost twice as great as during the previous year of peace (1897). In many instances wetting of the person, where an early cutaneous reaction is not secured, is followed by bronchitis. In barracks, many cases appear to be directly associated with the use of an excessive quantity of water for the cleansing of floors, with the damp atmosphere thus produced.

In the prevention of idiopathic bronchitis the avoidance of surface chilling, whether from insufficient protection, draft or wetting, is extremely important. Wet clothing should be replaced by dry as soon as possible, the body being wiped and rubbed vigorously to restore capillary circulation. The barracks should be dry, warm, and well ventilated without being drafty. The clothing issued should be of good quality and suited to the climate and season. More than that, its proper use should be enforced, and soldiers should not be allowed to go from warm barracks into a cold, damp atmosphere without donning additional protection or seeing that their outer garments are well buttoned up. On guard, especially in wet or foggy weather, it is important that the person be well protected. When men are wet and chilled from exposure the issue of hot soup or coffee is desirable. During a march in cold or wet weather, it would seem that mouth-breathers are more liable to be affected with bronchitis. As far as possible, duty which implies exposure to inclement weather should be avoided. There is no doubt that troops long in the field and habituated to exposure are less liable to contract bronchitis as a result of such exposure.

RHEUMATISM AND MYALGIA.—Under this heading are included, in our official nomenclature, all affections of a rheumatic nature not specifically diagnosed as rheumatic fever. Until 1884, rheumatic fever was also included in figures for rheumatism in general, and hence statistics for subacute and muscular rheumatism are not satisfactory prior to that year. These affections are responsible for a large amount of inefficiency and loss of service, notwithstanding the fact that many such cases, through their insignificance, receive treatment and are returned to duty without being taken up on sick report. On the other hand, it is probable that the rates for subacute rheumatism and myalgia are unduly raised by fraud, since these affections are the ones most frequently selected by malingerers for simulation. Since 1884 the admissions to sick report for these causes, per thousand strength, have been as follows:

Period.	Admissions.
Decade 1884–93	83.34
Year 1894	63.33
Year 1895	64.08
Year 1896	79.33
Year 1897	65.12
Year 1898	72.88

While the cause of these affections is unknown, they are markedly influenced in their frequency by moisture, and to a less degree by cold. They attain their maximum prevalence among troops in this country in early spring and late fall, coinciding with the periods of greatest rainfall. In their geographical distribution they are highest in those military departments in which the humidity is greatest; and in posts, in those in which damp casemates and old, badly constructed barracks are in use.

Among our troops the negro soldiers appear to be far more prone to affections of this character than the whites, the rates for these two classes being as follows:

Period.	Admissions per 1,000 white soldiers.	Admissions per 1,000 negro soldiers.
1884–93	79.68	121.60
1894	62.87	72.87
1895	61.40	95.07
1896	75.79	117.74
1897	61.80	100.74
1898	68.28	132.81

The great difference shown by the above figures is even more noteworthy when it is considered that the negro troops have, during the above period, been largely stationed in military departments in which, for white soldiers, the affections under consideration are of relatively infrequent occurrence. The figures for 1898, when both classes came under practically the same climatic influences, probably show very closely the greater susceptibility of the negro race. These diseases occur more frequently among young soldiers than among those of somewhat longer service, probably through greater carelessness with regard to exposure. In the class of very old soldiers the rate is, however, high.

In the prevention of subacute rheumatism and myalgia dryness of person and surroundings appears to be by far of the most importance. Wetting of the person by rain should, as far as possible, be avoided, and damp clothing and bedding should be at once removed and dried. Waterproof clothing, rendered impervious by the use of wool fat, should be issued; and all clothing should be sufficient and adapted to climate, season, and weather. Barracks should be warm, dry, and well ventilated, should have a sunny exposure, and should be located on a dry site. The use of casemates as quarters for troops is to be vigorously opposed. Where these affections largely prevail in a post or barrack, a general inspection of cellars and foundation walls is indicated.

Acute Articular Rheumatism.—Figures for the United States army with regard to the prevalence of rheumatism are not comparable for the period prior to 1884 with the period subsequent to that year. From 1861 to 1884 the official nomenclature included all forms of rheumatism under the same heading; but from 1884 to the present time the differentiation of rheumatic fever has been required. Since the year just named, the admission rates for acute articular rheumatism have been as follows:

Period.	Admissions per 1,000 strength.
1885–94	5.10
1895–98	5.26
Year 1897	4.36
Year 1898	7.03

These rates for acute articular rheumatism are much lower than those of nearly all foreign armies. In the German army the occurrence of this disease has been as follows

Period.	Admissions per 1,000 strength.
1881–82 to 1885–86	9.2
1886–87 to 1890–91	9.8
1891–92 to 1895–96	8.9
Year 1895–96	7.7
Year 1896–97	6.8

In the Austrian army the rates for acute articular rheumatism appear to be higher than in any other service, during the past few years having attained the following high proportion

Year.	Admissions per 1,000 strength.
1893	11.3
1894	12.2
1895	11.6
1896	10.4
1897	9.2

The true nature and origin of acute articular rheumatism are still unknown. Taking into consideration the many forms in which the disease manifests itself, it is certain that no neurotic theory and no theory of perverted metabolism can fully account for all the phenomena presented, many of which strongly suggest a microbic infection. No micro-organism has as yet been shown to be the cause of rheumatism; but the same is also true of such undoubtedly microbic diseases as measles, scarlet fever, whooping-cough, and syphilis. The strongly marked hereditary predisposition to rheumatism causes no difficulty, for the same fact is observed in tuberculosis. That exposure to cold and wet is often a factor in the causation of a rheumatic attack is analogous to what is often observed in pneumonia. Exposure, however, is a factor of such importance in the occurrence of rheumatism in the military service that, in default of accurate information as to its specific cause, the disease is most conveniently classed with those induced by cold, wet, dampness, and exposure.

Rheumatism, in its prevalence, has a certain relation to season. Coustan showed that for the French army the amount of rheumatism was much greater during the winter months than during spring or summer; in autumn, rheumatism was only about one-third as prevalent as in winter. Local conditions, as shown by statistics for our army, appear to have far more influence upon the occurrence of rheumatism than do geographical considerations. Race exerts a certain influence; the admissions for this disease being lower for white troops than for colored troops. Age is a factor of some importance, the rates for the seven years 1890–96, per thousand strength, being as follows:

Age.	Admissions per 1,000 of each class.
19 years and under	8.61
20 to 24	5.71
25 to 29	4.11
30 to 34	4.06
35 to 39	4.26
40 to 44	5.01
45 to 49	5.58

There appears to be no great difference, with reference to the branch of service, as regards liability to rheumatism. Exhaustion and chilling—especially wetting—often appear to markedly favor the disease; yet it undoubtedly happens at times that regiments may be long exposed to damp, wet, cold, sudden and violent changes of temperature, and be obliged to sleep on wet ground with but scanty protection, yet no cases of acute rheumatism follow. The disease appears to be less prevalent in garrison than in the field; when it occurs in garrison it would seem that the causative agent finds its most favorable field for development in damp, illy drained barracks and casemates, and the same applies to damp bedding or clothing. Recurrences of rheumatism may be fresh infections, or they may possibly be caused by renewed activity on the part of germs lying quiescent in some part of the organism, as with tuberculosis. As the individual who has been infected with syphilis is always syphilitic, so it may be that the soldier who has once suffered from rheumatism may be permanently rheumatic, and temporary diminution of the powers of vital resistance by chilling may suffice to produce a second attack.

It is evident that, in the absence of knowledge as to the etiology of acute rheumatic fever, it is difficult to formulate any definite plan for its prevention. As a matter of the first importance in reducing the rates for rheumatism, all those once affected with the disease should be eliminated from the service. Much may be done toward preventing the development of rheumatic attacks among soldiers by insuring dry, sunny barracks; by frequent exposure of bedding and clothing to the sun; by the prompt changing of wet garments; and, in the field, by the location of camps on well-drained sites and the adoption of measures calculated to keep the men above the surface of the ground while asleep. A sufficiency of clothing, especially of woollen material, is of importance

Affections Depending on Extremes of Temperature.

Insolation.—Sunstroke is one of the most serious calamities that may overtake troops in the tropics; and prostration and the extinction of vitality by extreme heat are also common in temperate climates during the heated period. Military history is full of instances of the disastrous effect of sunstroke. It is reported by Morehead that in India, in 1858, the Seventy-first Regiment lost 89 men by death from insolation between the 5th of May and the 15th of August. The frequency of sunstroke among the British troops in India was very great when the soldier carried the same weight and wore the same clothing as in England, but became much rarer when special modifications were adopted for tropical service. In the expedition of General Bugeaud in Algeria more than 200 men were reported as having been sunstruck; but in the operations of the French army in Mexico insolation was rare, probably through the altitude of the region in which the campaign was conducted. Viry states that, on July 8th, 1853, two-thirds of a Belgian regiment were struck down by heat during a march; and that during the last war in Italy, on a hot July day, no less than 2,000 men of one division of the French army fell in the ranks from sunstroke. In 1878 the Austrian troops occupying Bosnia lost many men from this cause; one regiment on the march having 320 cases with 31 deaths, while the total number of cases of insolation during the campaign amounted to 2,131. Sunstroke is said to be particularly common in Germany, and it is stated that on May 21st, 1827, the troops manœuvring near Berlin were completely disorganized by heat—entire sections falling along the route and the cavalry losing many horses. During the recent war in South Africa the British lost many men from sunstroke. In our own service but little marching has, in the past, been done during the heated season, but during the ten years 1888–97 there were nevertheless 523 cases of heatstroke. During the campaigns in Cuba, Porto Rico, and the Philippines, the number of cases of sunstroke was very large.

It is excess of internal heat rather than sunshine which results in the phenomena known as insolation; and hence the condition may occur at night if the atmosphere, while hot, is saturated with moisture, and heat dissipation, as accomplished by evaporation of perspiration, is imperfectly carried on. Insolation rarely occurs at a high altitude and in a dry climate, no matter what the temperature. Laveran and Regnard have found that as soon as the bodily temperature exceeds 40° C. (104° F.) it begins to exercise a marked influence upon the nervous system, the effect being greatly increased if the head is exposed to the direct solar rays. Death results from primary stimulation and subsequent paralysis of the nervous system by heat. Exercise is a great factor in the production of heat-stroke. Animals made to undergo violent exertion succumb more readily than do those allowed to rest quietly—and in the army it is the infantry troops which are most affected, cavalrymen being less liable to sunstroke than are their horses. Exercise greatly raises internal temperature, and Hiller found that the rectal temperature in soldiers after a hard march was that of a high fever. Anything which interferes with the loss of body heat increases liability to sunstroke; this including too heavy clothing, diminution of perspiration through deficient water supply, or lowering of the processes of evaporation through excessive humidity. If the atmosphere is both hot and moist, the loss of heat by the lungs is largely impaired; and in a marching column carrying with it a close atmosphere saturated with moisture, the men in the centre of the ranks are the ones most liable to sunstroke. The period of digestion is favorable to insolation; and debilitated or intemperate soldiers are the most in danger. Insolation is undoubtedly aided by the pressure of tight uniforms or of the belts and straps by which the soldier's load is suspended from his person. McCartie, in India, records a striking instance in the Chitral campaign of 1897, when sufficient coolies could not be obtained and part of the baggage had to be carried by native soldiers. Before the end of the march nearly all the men in the ranks were completely exhausted, and some had heat apoplexy, while their companions, carrying a much heavier weight but having assumed the light and loose native dress, were not in the least disturbed.

Some of the symptoms of heat-stroke are said by Notter to be caused by the reflected rays of the sun through the orbit. In the British service neutral-tinted glasses are frequently worn in the tropics, and were found of much value in the Egyptian campaign of 1882.

The advance to the condition of insolation is gradual, and its occurrence can be largely prevented by proper observance of sanitary detail. The march should be so planned as to avoid exposure during the heat of the day; and, if possible, the direct rays of the sun should not fall on the men's backs while marching. The length of the distance ordinarily traversed in temperate climates or cool weather should be diminished, or rapidity of movement lessened. Usually, in hot weather, a march of ten miles must be considered a good day's work. The weight to be carried should be reduced to the minimum. In the tropics troops should carry nothing but the arms, ammunition, and canteen; a sufficient number of coolies, pack animals, or wheeled vehicles being provided to secure the transportation of the baggage and the remainder of the equipment. Troops should march in as open order as possible the better to allow access of fresh air to each soldier. Halts should be as frequent as possible, and at points well shaded, elevated, and airy. For such stops ravines, especially if dry or sandy, should not be chosen. During such halts the men should not lie down, since in very hot weather, particularly if the ground be bare, the soil is heated to a greater degree than the atmosphere. Soldiers should have plenty of water, and canteens should be replenished as often as a suitable supply is encountered en route. Where the supply of water is liable to be insufficient, special arrangements must be made for its carriage with the column. The use of alcohol before or during a march should be interdicted. The clothing worn should be suited to the climate or season, should be loose, and should well protect the head and back of the neck. Since sunstroke is by many believed to be due to the actinic solar rays, the lining of the hat and blouse with dark green cloth may be desirable. A heavy meal should not be taken immediately before marching. Company officers should watch their men carefully with respect to sunstroke. If a soldier looks pale, weak, and exhausted, he should be spoken to sharply, and if he does not respond clearly he should be told to fall out and rest or await transportation. By this precaution many cases of insolation may be avoided. When the condition of isolation has once occurred, the soldier is usually unfitted for further military service, being particularly liable to future recurrences. For the military service it may be accepted that "once sunstruck is always sunstruck."

Congelation. — While sledging expeditions in the Arctic have been exposed without suffering to continuous cold of as great an intensity as −50° F., soldiers, on the other hand, have often been known to succumb to cold in comparatively mild climates and when the thermometer registered by no means a very low temperature. It may fairly be considered that accidents from this cause are relatively more frequent in the cold weather of temperate climates than in the far north, probably because of the more careful precautions taken for the conservation of the body heat under the latter conditions of climate.

Since the famous retreat of the Ten Thousand, when the rigors of climate destroyed more Greek soldiers than did the Persians, great cold has frequently exerted a strong influence upon military operations. Voltaire states that in the winter of 1709 a large part of the army of Charles XII. was destroyed by cold, 2,000 men being frozen to death during one march. In 1719, 7,000 Swedes, on their way to the siege of Drontheim, perished in the mountains between Sweden and Norway; while in 1742, in the retreat from Prague, 4,000 French soldiers died from cold and exposure. The sufferings of our own forces at Valley Forge, during the Revolution, are a matter of history; and in the destruction of Napoleon's army in Russia cold was by far the greatest factor. During the Crimean War, according to Viry, there were 5,290 cases of frostbite with 1,179 deaths among the French troops; while among the English forces the numbers amounted to 2,852 and 463 respectively. Laveran states that during the Franco-Prussian War, freezing of the feet caused much suffering in the French army and there were many deaths from cold. In 1879, according to the same authority, a column of 755 men in the field in Algeria, at the end of March, had 60 cases of frost-bite, of which 19 died. In our own service, during the decade 1888–97, there were 648 cases of frost-bite reported, of which 141 occurred in 1888. It should be remembered, however, that but a small part of our forces were stationed in regions in which congelation was liable to occur to any extent, and hence the cases reported were necessarily furnished by a relatively small fraction of the whole army. The history of congelation in armies shows that a state of low vital resistance, brought about by unfavorable hygienic conditions, plays almost as great a rôle as cold itself; and it is a matter of common observation that freezing occurs by far the most frequently among such soldiers as are weakened by fatigue, sickness, and privation. During the Crimean War the temperature encountered was never very low, and a report made at the time suggests that the large number of congelations observed might justly be regarded as "gangrene owing to scorbutic tendency exaggerated by cold." On the other hand, troops which are well fed and warmly clad resist the most intense cold without injury, as has been repeatedly shown in our winter campaigns against the Indians of the northwest. In the Powder River Expedition of 1876, conducted during the three winter months, with the mercury never above freezing and often down to −40° F., Rosse states that in a force of 2,000 men but 31 cases of frost-bite occurred, while in the 350 Indians with the command no cases were reported. During the winter of 1890–91, when about 6,000 troops were constantly in the field against hostile Indians, only 62 cases of congelation occurred in the entire army.

The phenomena which precede the death of the soldier from cold, while on the march, are well described by Larrey: "The dangerous condition is shown in the pallor of the face, by a kind of idiocy, by difficulty in speaking, by feebleness of vision or perhaps total loss of that sense; and in that state they march for a greater or less length of time, conducted by their friends; the muscular action is weak, and the individual totters on his legs like a drunken man. This weakness is progressive and is a certain sign of the extinction of life. Separated from the column and abandoned to themselves, they soon lost their balance, fell into ditches covered with snow, a state of lethargy ensued, and a few moments terminated their miserable existence."

Muscular contraction is sometimes seen, particularly of the neck muscles, together with symptoms like those of catalepsy. According to Forestius, soldiers have been found frozen standing with their arms in their hands; and the same thing was observed by Larrey during the retreat from Moscow.

In the prevention of freezing, an abundance of nutritious and fatty food is second only in importance to sufficient and proper clothing. The extremities are usually the chief points of attack, owing to their relatively poor protection and distance from the main sources of systemic heat. The feet particularly are susceptible to frost-bite, a fact showing the necessity of warm protection and water-tight, loose, and comfortable footwear. To protect the hands, heavy gloves or mittens are essential. The latter are preferable, and the Japanese army uses a mitten with a single division into which the trigger finger can be slipped when desired. It is of advantage, in diminishing the effect of cold upon exposed surfaces, particularly when marching in driving snow storms, thoroughly to anoint the parts with some greasy substance, as beef, pork or mutton fat, or vaseline. Whenever possible, hot food or drink should be served out to troops on the march, unless the latter be short—stops being made and fires kindled for the purpose. In the Russian and Austrian armies, during cold weather, kettles filled with hot soup and enclosed in heavy felt are carried in wagons with the column. Even in the coldest weather the soup is said to remain warm for four or five hours. If a march must be made in extremely cold weather, it should be got through with as soon as possible without undue fatigue, the ranks being kept well closed up and straggling being prevented. In general, however, if an army is well fed, well clothed, and free from sickness, it can undertake a winter campaign with perfect safety, provided the distances to be covered are not too long.

Guard duty is particularly dangerous during cold weather, and sentinels should be kept on post not more than an hour at a time, or a running guard may be established. When relieved from sentry duty, soldiers should not be permitted at once to lie down, but should be required to pace briskly around the fires until numbness has worn off. Under stress of severe weather men should be told off to keep up the fires.

SNOW-BLINDNESS.—The glare of bright sunlight upon fields of snow produces the condition known as snow-blindness, particularly when troops are subjected to prolonged marching toward the end of winter or in the early spring in cold climates. Since in our service soldiers are ordinarily housed in barracks during cold weather, the admission rate for this cause is usually low. Where field service is required in winter the rates are much increased; and during the winter of 1890–91, when our troops were engaged against hostile Sioux, there were 133 admissions to sick report from this cause. In a company fifty strong marching sixty miles in Montana during three days of March, 1894, nearly the entire command was rendered unfit for duty by reason of snow-blindness.

The condition may usually be prevented among soldiers by smearing the eyelids and upper part of the cheeks with a mixture of charcoal and grease; but when exposure is constant some further protection is necessary. For this purpose dark goggles, fitted in frames covered with chamois skin, have been recommended. The "snow-eyes" of the Esquimaux are made of light wood with the bridge resting on the nose, like spectacles, and presenting narrow transverse slits for the passage of light. These are said to be superior to goggles as a protection, can be readily made by the men, and are not liable to the accident of fracture. Under any circumstances where snow-blindness is to be apprehended, the men should be marched in close column and each soldier directed to keep his eyes on the dark clothing of the man in front of him, the leading rank being changed frequently to the rear.

DISEASE DUE TO IMPROPER DIETARY.

SCURVY.—*Occurrence.*—Scurvy, from time immemorial down to a comparatively recent period, has been the scourge of armies, especially during campaign. In the thirteenth century scurvy ravaged the hosts of the Crusaders; and it appears to have been almost continually present during active military operations until within the last score of years. The history of its epidemics could be multiplied almost indefinitely. At Thorn, in 1703, during the Spanish siege, 6,000 men died of scurvy. During the Napoleonic wars it crippled the efficiency of the French troops in Egypt; in 1801, and in 1807 and 1808, it ravaged the garrisons in Prussia. In the war of 1812 it was noted as largely occurring among our troops; and Rosse states that among 1,016 United States soldiers marching to and garrisoning Council Bluffs in 1820, the number of cases of scurvy was 516, and the number of deaths from this cause 168. The disease occurred among our troops, to some extent, during the invasion of Mexico; and for the eighteen years prior to the outbreak of the Civil War the average annual admission rate was 26.3 per thousand strength. During the Crimean War 23,365 cases of scurvy occurred in the French army; the Turkish force was almost destroyed by it, and the cases in the British army amounted to 17,557. In the various base hospitals at Constantinople, according to Marvaud, there were treated in 1855 no less than 14,879 cases, of which 1,407 died; in 1856 there were 10,295 cases with 1,509 deaths. It was present during our Civil War, and its recognition was a surprise and shock to professional ideas preconceived from practice in civil life. In spite of all effort to the contrary, there were 46,913 cases of this disease during the period 1861–66, giving an admission rate of 19.80 per thousand. There were during the same time 771 deaths directly ascribed to scurvy; but, obviously, no record of its well-known influence in bringing other diseases to a fatal termination was to be made. After the conclusion of the Civil War the disease prevailed to a great extent among troops serving at frontier stations, there having been 887 cases in 1868 and 211 cases in 1869. There were 115 cases in 1871, after which the rates for this disease fell rapidly on account of the greater facilities afforded troops for procuring vegetables—both by better means of communication and from the gardens which were gradually established at military posts. In the first few years after the Civil War there were several minor outbreaks of great severity.

During the Franco-Prussian War, while the number of cases of scurvy was not great, a general scorbutic tendency was thought to have done much to increase the mortality of the troops. Rosse states that in the Russian army, in 1873, the number of cases amounted to 5.3 per cent. In the Russo-Turkish War of 1878 it was present in both armies. In our own service, for the decade 1885–94, there were 27 cases, of which 18 occurred in 1888 and 5 in 1889. From 1892 to 1898 inclusive, only a single case was reported. The addition of fresh vegetables to the ration, in 1890, was undoubtedly most potent in removing the scorbutic predisposition previously existing among our troops. In the British service a few cases, in spite of all precautions, are constantly present; particularly among troops in India, in which for the decade 1887–96 the rate of admission was 7.4 per thousand. The admissions for the decade 1888–97, for the entire British army, were .4 per thousand. In the German army in 1897 there were reported 74 cases of scurvy and purpura. Coustan states that, in the French service, a number of minor outbreaks have recently occurred among troops stationed in Algeria. For the Russian and Austrian armies, the rates of admission per thousand strength have lately been as follows:

Year.	Russia.	Austria.	Year.	Russia.	Austria.
1892	1.7	1.7	1895	1.5	1.4
1893	1.9	2.3	1896	1.3	1.0
1894	1.7	1.2	1897	1.2	1.0

Through a better knowledge of its etiology, scurvy is now quite rare among troops. Its insidious character, however, favors a possibly unnoted invasion, its infrequency renders it unfamiliar, and the very knowledge of the means possessed for its prevention gives a false idea of security. It is a mistake to regard scurvy as being attendant solely on the unhygienic conditions of past centuries, long voyages, famine diets or special cases of privation. The dyscrasia, for troops in the field, is rather to be regarded as merely latent and requiring but a temporary interference with the distribution of supplies, and a brief subjection to depressing influences, to render its existence apparent; though not necessarily in the aggravated form with which the continued action of its cause characterized it in former times. The imminence of scurvy, where a proper nutritive standard is departed from, should be fully appreciated by the sanitary officer.

Cause.—Scurvy is due to an illy balanced dietary in which fresh vegetables and their salts are deficient. Salt meat, and fresh meat which has undergone putrefactive changes but is still eatable, are considered to favor the occurrence of scurvy. As predisposing causes may be mentioned excessive fatigue or overcrowding of quarters. Cold and humidity are also powerful factors, although scurvy is by no means uncommon in warm climates. Besides these, depression of spirits, nostalgia and lack of exercise play no unimportant parts. As illustrating the latter point, an instance is given in which a number of prisoners of war were removed on board ship and fed on exactly the same diet as those on shore. The prisoners on ship contracted scurvy—those on shore did not.

Scurvy, occurring in the military service, usually at once assumes an epidemic character, through the reason that large numbers of men are at the same time exposed to the conditions to which the disease owes its origin. From this fact, scurvy was long thought to be contagious. The disease is a great respecter of military rank and rarely occurs in officers, a fact due to their better nutrition and lessened exposure to depressing conditions. It has a marked tendency to attack convalescents—and may frequently be associated with other diseases, to whose attacks it imparts additional severity. In the Crimean War, typhus occurring in a scorbutic patient was said to have been uniformly fatal. Winter is particularly the season when scorbutic manifestations appear, this being the season when fresh vegetable material is scarce and troops are largely confined, through the inclemency of the weather, in the vitiated air of their quarters. Sometimes, however, scurvy occurs in the autumn. This was the case at the Crimea, when, in a period of three months, 500 cases occurred among the French troops.

While the symptomatic diagnosis of scurvy is not a subject for discussion, it may be here remarked that scurvy, in the military service, is usually seen in the early stages, at which time it not infrequently simulates muscular rheumatism and is liable to be mistaken for the results of simple exposure to wet and cold. The characteristic symptoms of the disease are later manifestations. Among the conditions not infrequently present as a result of scorbutus are acrodynia and hemeralopia, or night-blindness. Both have prevailed epidemically in armies. Hammond noted the presence of hemeralopia among our troops in Kansas and New Mexico, and even as late as 1884 it figured in the returns for the army. During the Crimean War both French and English were attacked, and after the capture of Sebastopol the number of hemeralopics was so great in the French army that certain regiments could not furnish the necessary number of men to mount guard. The condition has repeatedly been caused to disappear by improvement in the character of the food supplied. In this connection, mention may be made of ulcerative stomatitis, which, formerly common in armies, is now rare. This affection undoubtedly depended upon a scorbutic tendency and lowered powers of resistance resulting from malnutrition. Coustan mentions 19 epidemics of it as having occurred in the French army between the years 1793 and 1877.

Prevention.—Scurvy is entirely avoidable, and its existence is a reproach to the sanitary officer. The disease would rarely occur if the character of the food supplied corresponded with the natural cravings of the individual, and it is only where the use of a restricted and improper diet is required that its occurrence is possible. At the present day its existence is evidence of lack of sanitary administration or short-sighted economy—either being inexcusable. The prevention of scurvy is accomplished by the administration of citric, tartaric, malic, acetic and lactic acids or their salts. These are best given in the juices of fresh, succulent vegetable material; fresh fruits, tubers, roots and leaves being better than seeds, while the leguminosæ have no antiscorbutic virtues. The raw potato, onion and tomato are especially valuable. Fresh cabbage is excellent, being better than sauerkraut. Radishes are also valuable. Where such vegetables can be obtained in abundance scurvy will not appear. For troops in the field the dandelion and lamb's quarter are frequently available, and may be boiled and eaten as greens. The yellow mustard and cresses can be used as salad, while the young shoots of the pokeweed serve an excellent purpose as a vegetable. In some regions the so-called scurvy grass, or cochlearia, will be found. Woodhull especially recommends the agave as an antiscorbutic. To prepare it the leaves are cut off close to the roots and cooked well in hot ashes. The juice is expressed and taken, either raw or sweetened, in the proportion of one to four wineglassfuls several times daily. The white interior of the leaves may be eaten. All the varieties of the cactus are useful, in the absence of other vegetable material, in the prevention of scurvy. In general, fresh vegetable matter of any variety can be used with advantage, provided only that it has no harmful qualities. Made into soups, nearly all are tolerably palatable.

Wherever the authorized issue of vegetables is scanty, the supply should be increased, from outside sources, by every means possible. Dried vegetables are antiscorbutic, but much less so than the fresh; the vegetable acids being probably decomposed by heat and keeping. When the vegetables are desiccated and compressed, a considerable proportion of these acids and their salts are removed, and what remains is too often largely cellulose. It is said, however, that our forces in the expedition to Utah, against the Mormons, owed their preservation from scurvy largely to the use of desiccated vegetables, at a time when nothing else of an antiscorbutic nature could be obtained. The use of fresh vegetables should never be superseded by the preserved article when the former can be obtained. Fresh fruits, especially lemons, limes, grapes, oranges and acid fruits generally, are excellent antiscorbutics. Even unripe fruits are better than none, and diarrhœa may at times be hazarded for the sake of their valuable properties. Dried and canned fruits are also of advantage. Preserved lime juice has been much used on shipboard in the prevention of scurvy. It has long been employed in the British army and navy, and forms part of the British field ration, in the proportion of half an ounce daily, in the absence of fresh vegetables. Excellent results have long followed its use, and it could be adopted with advantage in our own service for similar conditions. Good beer and wine appear to have decided antiscorbutic value. Spruce beer has been made and used with advantage. Vinegar, one-half to one ounce daily, should be used in the cooking or taken with pickles; it was much used as an antiscorbutic in the armies of antiquity. It has long been known that those who eat large quantities of under-done fresh meat, even though a limited amount of vegetable material is used, escape scurvy. This antiscorbutic quality of meat is largely destroyed by cooking, probably through the splitting up, under heat, of the lactic acid which it contains. It is a matter of common observation that Indians and Esquimaux, who may eat no vegetable material for considerable periods but who habitually use meat either raw or in a partially cooked condition, are not affected with scurvy—and the same is true of whites who follow their example. At times when scurvy was very prevalent in our western garrisons, the hunting parties sent out to procure fresh supplies, living largely on under-done flesh, were notably exempt from this affection. The value of raw meat as an antiscorbutic has been repeatedly noted by Hayes, Kane and other Arctic explorers. Kane wrote: "Had we plenty of frozen walrus I would laugh at scurvy." Pemmican, prepared with fat, sugar, raisins and currants, is an excellent antiscorbutic for cold climates and is much in vogue with travellers in the far north.

Where fresh vegetables cannot be obtained, the administration of the vegetable acids, especially tartaric and citric acids, combined with an alkali, is highly desirable to prevent the occurrence of scurvy. Since the disease is favored in its occurrence by confinement, impure atmosphere, cold, dampness and mental depression, any unfavorable conditions of this character should be remedied and every effort made to elevate the physical and mental tone of the soldier.

Diseases Dependent on Military Service.

Irritable Heart in Soldiers.—A well-defined group of symptoms, for want of a more scientific designation known as "irritable heart of the soldier," has received considerable attention from military and medical writers in this country, notably from Taylor and Da Costa. The condition is one which was long practically found only in soldiers, but is now not infrequent in athletes and is common in bicyclists. At the outset the trouble is purely functional in character, but when the exciting influence is long continued it is capable of ultimately producing organic lesions. Many different degrees of the affection are therefore observed.

The condition usually occurs in young and untrained soldiers, especially when weakened by disease or privation, during the occurrence of forced marches and particularly in warm weather. The general symptoms may be indefinite, but the soldier usually complains of pain in the chest and inability to carry his equipment on the march without losing his breath. The pulse is weak, intermittent and dicrotic, and there is the general appearance of exhaustion. Often there is dizziness, which may be more pronounced at night. In more pronounced cases there are gastric disorders, the mind, memory and voice are temporarily enfeebled and the walk is weak and uncertain. Slight murmurs may be noted, and there is usually dilatation of the cardiac chambers, often excessive. The right ventricle is the one usually dilated because of its thinner walls and the greater proportionate strain to which it is subjected. The action of the heart may be seriously impaired or even paralyzed through the stretching and separation of the muscular fibrillæ. Permanent and serious impairment of the cardiac function at times results, though the symptoms of heart strain may disappear as long as active exertion is not required. A number of cases immediately fatal through cardiac paralysis have been noted, although the condition must be regarded rather as chronic than acute.

As a result of an examination of a body of soldiers who had marched a distance of fifty miles, Teissier noted that the apex of the heart was displaced outward, that its breadth was increased, and that the venous circulation was impaired. The action of the heart was short and irregular, and a well-defined cardiac murmur was present. The arterial pressure was considerably lowered. Similar results were observed by Coustan. According to Taylor, at the battle of Corinth, during the Civil War, of two companies which had engaged in a lively reconnaissance one-fourth of the men returned in a state of complete exhaustion, while three men had dropped from the ranks from cardiac syncope and were supposed to be dead.

The condition is brought on by great physical exertion, particularly in the absence of preliminary training, and especially in such men as may be affected with latent cardiac weakness, not discoverable on ordinary physical examination. The habitual use of alcohol and tobacco appears to favor it, but syphilis has not been shown to play a part in its occurrence. Restricted respiratory function should be regarded as an important exciting cause of heart strain, and its occurrence is largely favored by the mechanical compression of the chest wall by tight clothing, belts, and the weight and mode of carriage of the equipment. With modern improvements in these respects the affection has become less frequent.

Coustan states that cardiac irritability not rarely occurs in cavalry soldiers, especially inexperienced riders mounted on hard-trotting horses.

Irritable heart generally has a good prognosis so far as the individual is concerned—but even under the most favorable conditions the soldier is usually disqualified for future hard service; for the same influences which originated the affection will operate even more powerfully in a weakened organ.

Should a soldier on the march present symptoms of heart strain, any tight clothing should be loosened, his equipment removed and he be furnished with wheel transportation. Continuance of exertion in such a case can result only in serious permanent injury to the individual. The treatment is symptomatic, with rest as an essential feature. Prophylaxis depends upon the elimination from the military service of soldiers who at any time show symptoms of cardiac weakness. The length and rapidity of marches should be kept within reasonable limits, and soldiers, especially raw troops, should not be forced to perform tasks beyond their powers except under pressing military necessity. The weights carried should be as light as military conditions permit, and should be properly disposed upon the person. Any constriction of the chest should be avoided.

Febrile Exhaustion.—A so-called "fever of exhaustion" has been described by Coustan and others. The affection often occurs in troops during campaign or hard marches, especially in warm weather. It occurs chiefly in infantry after rapid marching, but mounted soldiers are not infrequently affected. Recruits are particularly liable to its occurrence. The symptoms are somewhat variable, but include a remittent temperature, a tendency to adynamia and marked nervous depression. Usually there are headache, insomnia, restlessness and severe lumbar pains. The urine is scanty, red, and turbid, but becomes clear in about twenty-four hours. The muscles which have been excessively fatigued are sometimes sore to the touch for several days. Diarrhœa is a prominent symptom, and during a severe march the alvine discharges of the men become noticeably frequent and watery. Vomiting not rarely occurs. The condition is generally regarded as being due to an excess of acid produced in the muscles under the influence of muscular work, and in its action on the muscular fibres it diminishes their contractility. The local pains are thought by some to be due to minute lesions occurring in the muscles as a result of excessive use, and resembling those which occur from prolonged massage. The substances given off as a result of muscular work may affect the nervous centres in the production of nervous depression and fever; while the diarrhœa probably depends upon relaxation of the mucous membrane and upon the large amounts of fluid drunk to replace the losses by perspiration.

The prevention of this affection obviously depends upon proper conduction of the march. The treatment includes rest, with sometimes warm baths.

Feigned Diseases.—No reference to the diseases of the soldier would be complete without mention of the intentional simulation of disease—not uncommonly observed in the military service, and for the detection of which medical officers are constantly on the alert. The feigning of diseased conditions of mind or body has always been a favorite method with all classes of people for securing betterment of condition, relief from distasteful duty or the evasion of punishment, and this is particularly the case among soldiers, whose medical assistance is gratuitous and whose pay and subsistence are assured without the necessity of securing them by constant personal effort.

By far the most elaborate and persistent efforts at deception are those which occur in time of war, when recruits endeavor to escape draft or to avoid duty on the firing line. In time of peace the conditions simulated are usually simple, and the claims as to their existence are not long continued. Sometimes, however, as where an effort is made to secure discharge from the service, the symptoms feigned are extremely complex and are maintained with great pertinacity. The disease selected for simulation, and the persistency with which its symptoms are exhibited, are for the most part determined by the familiarity possessed, or thought to be possessed, by the malingerer with reference to it. In general, some morbid condition the symptoms of which are largely subjective, as muscular rheumatism or neuralgia, is selected. Another condition not infrequently simulated is that of involuntary nocturnal enuresis, and this fraud, with the above, is especially difficult of demonstration. Among the affections feigned may also be mentioned various fevers, diarrhœa, dysentery, chorea, epilepsy, hysteria, hemorrhages, apoplexy, imbecility, insanity, coma and even death—in fact, the diseases simulated belong to every department of medicine. Not infrequently such a varied array of symptoms is presented to the medical officer as would scarcely suggest any known affection. The degree of success of the attempt at simulation naturally depends upon the skill with which it is executed, and this is influenced by a more or less comprehensive knowledge of the symptoms of the affection selected and the degree of natural cunning possessed by the malingerer. Usually the imitation is imperfect and readily to be detected; but occasionally an instance is found in which every effort to prove the case to be fraudulent, even where it is a moral certainty that such is the fact, meets with only negative results. In most instances, careful questioning and observation suffice to expose the fraud. In other cases it often becomes necessary, while apparently agreeing as to the reality of the affection, to confine the patient to bed, place him on low diet and administer disagreeable potions. Under such treatment recovery is usually rapid. Where rheumatism or neuralgia is simulated the use of the actual cautery may be advisable, but in general every case must be treated according to circumstances. At times the inconvenience and suffering unhesitatingly endured by the malingerer are truly remarkable.

The prevention of malingering can be largely accomplished by careful investigation of each case on the part of the medical officer, whose knowledge of the personal character of the individual, gained by contact or by inquiry of his company officers, will largely aid him in arriving at a correct conclusion. Men of unstable or undesirable character, who present no objective symptoms of disease, should in general be promptly returned to duty. Where conditions are such that the fraud can be definitely proven—which, unfortunately, is rarely the case—the offender should be tried by court-martial and severely disciplined. In general, the personality of the medical officer is a factor of no small importance in determining the amount of malingering in a command.

Edward L. Munson.

CAMPANULACEÆ.—(The Harebell or Lobelia Family.) This family, of some two score genera and more than a thousand species, is of greater interest through its poisonous species than through its medicinal value. Its plants represent every habit, though the most of them are herbs and there are no large trees among them. The juice is milky and the flowers are mostly showy. They inhabit all except very cold countries. Of the three sub-families, the first, *Campanuloideæ*, is much more closely related, in composition and properties, to the distinct family *Cichoriaceæ* than to the remainder of its own family, and it appears, from various considerations, to be a mistake to class these and the third sub-family, *Lobelioideæ*, in the same family. The Campanuloidæ are not poisonous, but, on the contrary, produce numerous wholesome and nutritious roots, containing inulin, and some of their fruits also are edible. Of the Lobelioidæ, on the other hand, one or more species will be found recognized in almost every country as deadly poisons. The poisonous constituents are chiefly alkaloids. As poisons, they are classed as acrid narcotics, and act generally like *Lobelia inflata*, which see.

Henry H. Rusby.

CAMPHOID is a substitute for collodion made by dissolving 1 part of soluble gun cotton (pyroxylon) in alcohol containing 20 parts of camphor. It is a thick, colorless liquid which dries very rapidly, and when painted on the skin leaves a thin impervious film. It may be applied as a protective, or as a vehicle for iodoform, chrysarobin, tannic acid, etc.

W. A. Bastedo.

CAMPHOR.—*Camphora*, U. S. P., Br. P., $C_{10}H_{16}O$. A stearoptene imported in a crude state and purified in this country, by sublimation. The tree from which camphor is obtained is a member of the order Lauraceæ, and was named by Linnæus *Laurus camphora.* Nees and Ebermair classed it with cinnamon as *Cinnamomum camphora*, and later Nees separated it into a special genus as *Camphora officinarum.* It is a large tree, of slender habit, with long, horizontal, smooth, green branches, and a hard, light-colored, very fragrant and valuable wood. The alternate evergreen leaves are dark and shining above, lighter, glaucous-green beneath, ovate acuminate entire, three-nerved. Flowers minute, greenish-yellow, in small axillary panicles. Perianth thick, six-lobed stamens, nine with four-celled anthers opening by valves. Staminoides six. Ovary free, one-celled, one-seeded. Fruit about as large as a pea, surrounded by the persistent perianth tube. This tree grows extensively and abundantly in Formosa and the Japanese islands, from which places all the camphor of European and American commerce is obtained; and in Central China. It has also been transplanted and flourishes in most tropical or sub-tropical countries of both hemispheres.

Camphor is also obtained from other sources. The best known are the Borneo and Ngai camphors. The former is collected on the islands of Borneo and Sumatra from *Dryobalanops camphora*, the latter from *Blumea balsamifera*, which grows abundantly throughout China and India.

The increasing demand for camphor in the arts, particularly in the manufacture of celluloid and smokeless powder, is directing attention to its production, as the demand is exceeding the natural supply. To replace this deficiency the manufacture of artificial camphor is being improved, and the market will probably be supplied with camphor prepared from some of the turpentines, quite independently of the present source.

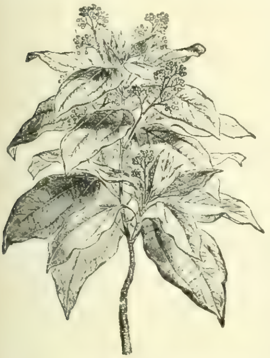

FIG. 1097. Camphor Tree, Flowering Branch. (Baillon.)

Camphor is a constituent, or more properly, an oxidation product of the essential oil of camphor, which is abundantly present in all parts of the plant. Very frequently the camphor is found in a more or less pure state beneath the bark, having separated from the oil. It is separated from the leaves, smaller branches, and chopped wood by a crude method of sublimation, in which impure condition it is exported. In this country it is resublimed.

Camphor occurs "in white, translucent masses, of a tough consistence and a crystalline structure, readily pulverizable in the presence of a little alcohol, ether, or chloroform; having a penetrating, characteristic odor, and a pungently aromatic taste. Specific gravity, 0.995 at 15° C. Very sparingly soluble in water, but readily soluble in alcohol, ether, chloroform, carbon disulphide, benzin, and in fixed and volatile oils. It melts at 175° C., boils at 204° C., and is inflammable, burning with luminous, smoky flame. On exposure to the air it evaporates more or less rapidly at ordinary temperature, and, when moderately heated, it sublimes without leaving a residue" (U. S. P.). The solubility of camphor in water is about 1 part in 1,300; this is increased by the presence of sugar, magnesia, carbonic acid, and spirits of nitrous ether. When camphor is mixed with menthol and similar products, in definite proportions, the two substances become a liquid. The following are some of the combinations: camphor 1 part—with menthol 3, with thymol 1, with chloral hydrate 1, with salol 1.5; camphor 2 parts—with naphthol 1; camphor 4 parts—with phenol 12 to which water, 1 part, has been added. With certain resins and gums, camphor forms a soft mass of pilular consistence, which lasts for a variable length of time according to the gum selected. Guaiac, asafœtida, galbanum, benzoin, and tolu are some that are of pharmaceutical importance.

The oil of camphor of commerce is separated during the first sublimation and is obtained as a thin fluid, varying in color from a light yellow to a reddish-brown according to age. It has a strong odor and taste resembling those of camphor. It is very variable in character, the percentage of camphor that may be present is uncertain, some samples being entirely free from it. The oil is not of much therapeutic value in this country, although thought much of in China and other Eastern countries, where it is employed not only for its remedial properties but also as a turpentine in the preparation of india ink and varnishes. It is also used as an illuminant. Its action is similar to that of camphor, and it is recommended in the same conditions in doses of from gtt. i. to gtt. iij.

Camphoric acid, $C_{10}H_{16}O_4$, is a product of camphor that is of much therapeutic interest. It is an oxidation product of camphor, and may be prepared by heating camphor with nitric acid. The acid forms in small colorless needles or plates, odor faintly aromatic, taste acid and bitter, very sparingly soluble in cold water, more soluble in hot, soluble in alcohol and ether. Ten per cent. of alcohol added to hot aqueous solution prevents the acid from being deposited on cooling. This acid has long been known, but it is only during the last few years that its therapeutic properties have been utilized. Its chief use is in the treatment of diseases of the respiratory tract and as a preventive of night sweats. For the latter purpose it promises to be one of the most valuable additions to our materia medica.

Compared with atropine, its effect is more certain and more prolonged, while it does not produce the difficulty in swallowing, dryness of the pharynx, disturbed sleep, and vertigo, which often accompany the use of the latter drug. Its mode of action differs from that of atropine, as its beneficial effect is thought to be due to its power of destroying the ptomaïns in the blood which cause this distressing symptom.

The dose as an anhydrotic is gr. xxx. at bedtime, or gr. xv. during the afternoon and the same dose repeated at bedtime. The action is not rapid, and in some instances no effect has been noticed until the following day. The effect of a single dose often continues for several days. The reports of cases treated show beneficial results in a great majority of them; it does not in any way interfere with the appetite or digestion, and in most instances a quiet sleep follows its use. As the taste is somewhat disagreeable, it is best administered in wafers or capsules.

In diseases of the mucous membrane of the respiratory tract, camphoric acid is used by applying locally and as a spray. In acute coryza, pharyngitis, and laryngitis, a half- to one-per-cent. solution may be used every three hours, or tampons saturated in the solution may be introduced into the nasal cavities; in ulcerated throat, a solution of two to six per cent. may be applied. This drug has no corrosive action; it possesses antiseptic properties and produces contraction of the blood-vessels of the mucous membrane.

Internally, it is also used for intestinal diarrhœa of a catarrhal character, and where intestinal antisepsis is desired, the dose is from gr. v. to gr. x.–xv. It is excreted by the kidneys and renders the urine clear and acid in two or three hours.

In cystitis, when the urine is alkaline, it has proved of benefit. In this condition it is also used as a wash in a half of one-per-cent. solution. The bladder is to be irrigated twice a day, about an ounce of the solution being left behind.

Camphor is absorbed from the skin and mucous membrane, and is found unchanged in the blood and the various organs and tissues. The kidneys do not excrete it unchanged, but it is thought to be excreted by the lungs and skin. In its action camphor is antiseptic and stimulant, with a sedative effect following the primary stimulation. This action is exercised upon the surface when applied externally, and when administered internally, the same effect is directed to the mucous surfaces with which it comes in contact. In the stomach it stimulates the muscular coats, adds a sense of warmth, and reflexly stimulates the heart and abdominal circulation. After absorption its action is directed to the cerebral and spinal centres through which it influences the heart and vascular system.

Camphor is not now employed to the extent that it was formerly. The difficulty of giving it in suitable doses, without deranging the stomach, has proved a serious obstacle, and other remedies have supplanted its use. When given in pill form, or in its pure state, it proves irritating to the stomach and has been charged with producing gastritis and ulcerations. When given as an emulsion, with sugar, gum arabic, and water, it forms a nauseous mixture. At present it is given in small doses, combined with other remedies, and the former doses of gr. x. and xv. are rarely heard of. It is of value in cardiac and circulatory depression, and in all conditions in which rapid stimulation is required; as in typhoid conditions, pneumonia, œdema of the lungs, and dilatation of the heart. In chronic depression of the nervous system when there is a loss of control it is a useful stimulant in repeated small doses. Hysteria, chorea, epilepsy, spermatorrhœa, and melancholia are some of the conditions in which it has been much employed. Its excretion by the skin and bronchial mucous membrane has made it a very useful diaphoretic and expectorant, and in febrile states, particularly when combined with opium and other diaphoretics, it has always been recognized as of much service. Its action upon the genito-urinary organs has been a disputed point. It is supposed to have a sedative action and also to possess anaphrodisiac properties. After its continued use it certainly acts as an anaphrodisiac. As a sedative it is combined with bromides, opium, and hyoscyamus. After its continued use and in large doses it excites the brain and produces a form of intoxication. Its continued use produces a craving for the drug, and it has been shown that a camphor habit may be acquired. In toxic doses there is over-stimulation, which is of very short duration and is rapidly succeeded by depression, with stupor or coma, paralysis, cold surface, clammy perspiration, and other symptoms of collapse, which may terminate in death.

Formerly camphor was given in doses of gr. x. and xv. It is now given in one-, two-, and three-grain doses, rarely exceeding five grains. It may be administered hypodermically, particularly in conditions of collapse. It may be given in pills or capsules, or in powder with sugar, or the spirits of camphor may be given in wine. The camphor may also be dissolved in ether and added to wine. The following forms a good emulsion: camphor, gr. xv.; ol. olivæ, ʒ ij.; mucil. acaciæ, ℥ v.; syr. simplicis, ℥ i. For hypodermic use, the spirits, ethereal solution, or camphorated oil may be selected.

Monobromated Camphor, $C_{10}H_{15}BrO$, is a substitution compound of camphor in which one atom of hydrogen is replaced by one of bromine. It is official in the United States Pharmacopœia. It occurs in colorless prisms, with a taste and odor of camphor. It is almost insoluble in water, but soluble in alcohol and fixed oils. It is permanent in the air and unaffected by light.

This camphor compound was introduced as a nervous sedative and antispasmodic. It has been employed in delirium tremens, hysteria, epilepsy, whooping-cough, chordee, spermatorrhœa, and numerous other conditions arising from disturbance of the nervous system. It has also been used as an hypnotic in insomnia of the same character. In all these conditions it has proved of service, but appears to be of most value in the milder forms of epilepsy. The dose is from gr. v. to gr. x., once or twice in twenty-four hours and gradually increased until the dose is repeated four or five times a day. When its administration is being pushed its effect requires to be watched, as when given in excessive doses to animals it produces muscular weakness, paralyses, and depression of the vital centres.

On account of its disagreeable taste it is administered in pill form, or in capsules, or perles. Elixirs are prepared by dissolving it in spirits and adding aromatics and syrup. An emulsion may also be formed by dissolving in sweet almond oil and forming an emulsion with gum and water.

Beaumont Small.

CAMPHOR SALICYLATE.—This is a compound of 84 parts of camphor with 65 parts of salicylic acid. It occurs as a crystalline, camphor-like mass, or it may be made to crystallize out from its solution in benzol. It is insoluble in water and glycerin, soluble in alcohol, in mineral oils, and in 20 parts of olive oil. Used internally as an intestinal antiseptic and carminative, it acts in the alimentary tract much like salol. Its systemic effect, however, is not marked, and its internal use has up to the present been confined mostly to the summer diarrhœas. The dose is gr. i. to v. In lupus and other skin diseases it is applied locally in the form of an ointment or liniment of from five- to twenty-per-cent. strength.

W. A. Bastedo.

CAMPHORONIC ACID.—Iso-propyl-carballylic acid —$C_6H_{11}(COOH)_3$. Obtained by the oxidation of campholic acid, it forms white, acicular crystals, soluble in water, and very hygroscopic. It is recommended as an antiseptic in aqueous solution. *W. A. Bastedo.*

CANADA BALSAM.—*Balsam of Fir.* Spurious Balm of Gilead. The liquid oleoresin obtained from lacunæ in the bark of *Abies balsamea* (L.) Miller. This fine, tall tree is abundant in the Northeastern United States, northward and northwestward. Its leaves are much in demand for making "balsam pillows," which are deliciously fragrant. Its buds are often sold as balm of Gilead buds, but this name properly applies to those of *Populus candicans*. The oleoresin is collected by breaking the blisters upon the bark and catching the exudation. It is of a pale-yellow color, absolutely clear and transparent, somewhat viscid, aromatic, and bitter. It is insoluble in alcohol and water, but dissolves in ether and chloroform. It possesses the ordinary stimulant antiseptic and expectorant properties of the family (see *Coniferæ*), and is given in doses of .3 to 2 gm. (gr. v. to xxx.). It is more largely used in microscopical mounting than otherwise, for which its perfect transparency peculiarly fits it. *Henry H. Rusby.*

CANADIAN HEMP. See *Apocynum.*

CANARY ISLANDS.—These islands, justly celebrated for their admirable climate and beautiful scenery, lie between the 27th and 28th north parallels of latitude, five degrees north of the tropics, and in longitude 13° to 18° W. They are in about the same latitude as Florida, Southern California, Southern Texas, Northern Egypt, and the Desert of Sahara. They are from 120 to 170 miles distant from Africa, and may be reached by steamer from Plymouth or Southampton, England, in from five to eight days; and from Cadiz, Lisbon, Gibraltar, Marseilles, or Genoa, in three or more days. The islands (of volcanic origin) are seven in number; but the two generally visited by invalids and always meant when the Canary Islands are referred to, are Tenerife and Gran Canaria, about 30 miles from each other. In these islands Las Palmas in Gran Canaria, and Orotava in Tenerife are the towns usually resorted to. The climate is characterized by medium dryness, a large amount of sunshine, equableness, and a stimulating quality; in brief, it is a moderately dry marine climate. "The Canaries lie in the region of the dry, northerly trade winds, which are the prevailing winds throughout the year, usually blowing about 240 days out of the 365, but more strongly and almost without break during the summer months; hence the mean maximum temperature of the summer months, which is about 77°, is lower than might be expected for the latitude" (Melland, "Climatic Treatment in Grand Canary," *Medical Chronicle*, Manchester, 1897, vol. viii., p. 321).

As both Tenerife and Gran Canaria are mountainous, the mountains rising to the height of 6,000 feet or more, there is both a shore and a mountain climate. For the summer, Melland considers the mountain climate superior to that of the shore in the treatment of lung diseases, and already hotels adapted for invalids have been erected in these higher regions. During the winter months Las

Palmas, of which Melland especially writes, is to be preferred, he says, for cases of early phthisis and rheumatism, to some of the other health resorts of the island, on account of the clear sky, free radiation, and abundance of sunlight. These advantages of Las Palmas are due to its geographical position away from mountains and northern slopes. The vegetation of these islands is rich and varied; the date, palm, pepper, and eucalyptus are some of the trees found there; and of fruits there are oranges, apples, pears, peaches, plums, figs, grapes, guavas, bananas, pomegranates, and prickly pears. The flora is very extensive and the variety of plants great. "Anything put into the ground will grow," says Mrs. Stone ("Tenerife and Its Six Satellites," by Olivia M. Stone; 2 vols., 1887).

The meteorological observations, taken at Las Palmas, are given by Melland as follows:

1889–93.	SHADE TEMPERATURES.				Bright sunshine, hours per diem.		Rain, inches.	Relative humidity, per cent.	Number of days any rain fell.
	Mean maximum.	Mean minimum.	Mean.	Range.	Hrs.	Min.			
October.....	73.4	65.8	69.6	7.6	5	30	3.22	73	7
November .	71.3	62.3	66.8	9	5	38	1.87	68.5	10
December..	67.6	57.2	62.7	9.7	4	50	1.86	68	12
January ...	66.5	57.3	61.7	8.8	5	3	1.41	66.6	8.5
February ..	66.5	55.7	61.2	10.7	6	9	.51	65.8	3.5
March	67.4	56.5	62.1	11.2	5	57	.84	67.6	5
April........	69.3	59.1	64.2	10.2	6	23	.34	67.3	4.5
May........	69.2	61.3	65.4	8.4	6	43	.38	67	4
Average for winter ...	68.5	58.8	63.6	9.7	5	41	8.15*	67.1	49*

* Total.

The small diurnal range of temperature is to be especially noted, as well as the slight variations from one month to another. The rainfall is very inconsiderable, and there is the small number of forty-nine days upon which any rain fell. Each day gave an average of over five hours and a half of sunshine. The relative humidity greatly decreases as one ascends into the mountain regions.

The following observations for Orotava are condensed from various observers:

Months of winter.	Average temperature, degrees.	Mean daily range, degrees.	Daily sunshine, hours per diem.		Relative humidity, per cent.
			Hrs.	Min.	
November.........	66.97	11.8	..	..	67.3
December.........	65.05	11.2	5	48	63.2
January...........	62.88	11.2	5	42	61.5
February..........	61.1	12.1	5	47	68.6
March..............	62.7	11.9	7	32	66.9
Average for winter	63.74	11.6	6	12	65.5

The temperature of Orotava, says Gihon (Transactions of the American Climatological Association, 1889), never falls below 50° F. or rises above 82° F., and attains these extremes only on rare occasions.

"The February of Orotava," continues the same writer, "is the June of London, the May of Paris, and the April of Rome, Nice, and Cannes." In Orotava storms are unknown, and linen garments may be worn the entire year. "Here, if anywhere," to again quote Gihon, "reigns perpetual spring, without fogs and frosts, where the sap never dies, where rain seldom falls, winds and storm are scarcely known, and burning heat is never felt."

From observations taken at Las Palmas, it is seen that the six warmest months are from June to November, with a mean temperature of 71.7° F.; and that the six coldest months are from December to May, with a mean temperature of 63.5° F. September and October are the hottest months, with a mean temperature of 73.5° F.; but they differ from the coldest month, February, by only 13.5° F.

The mountain climate of the Canaries, at an altitude of from 1,300 to 5,000 feet, differs from that on the coast by increased dryness—the relative humidity at the village of Villa Flor (4,300 feet) for the month of August being 35 per cent.; by the absence of the northerly trade winds; by the absence of rain during the summer; by a greater range of temperature; by a more invigorating atmosphere; and by almost continuous blue skies. The summer is the proper season for visiting the highlands, as the climate is then at its best. "Here," says Brown ("Madeira and the Canary Islands," by A. Lander Brown, London, 1896), "the invalid may live for months under a rainless blue sky and in a genial climate, wandering among gorgeous forests and magnificent precipices; below him a vast sea of billowy cloud out of which the summits of the other islands rise, beckoning him to new explorations." Melland considers the mountain climate much more rapidly curative in cases of early phthisis than that of the coast. In some of the mountain stations, as at Laguna (1,800 feet) in Tenerife, there are good accommodations, and camping is also not an infrequent method of living in the higher altitudes. Orotava consists of the town, or villa de la Orotava, at an altitude of 1,100 feet, and three miles distant from this is the Puerto de la Orotava on the coast; it is the latter locality to which invalids resort. Round about these two Orotavas and including them is the famous Orotava valley, which Humboldt considers "the loveliest scene in the world," and of which M. J. Leclercq, in the *Annuaire du Club Alpin Française*, 1879, writes: "I have seen sights more varied, more striking, and a more brilliant sky; vegetation is more thoroughly green in the celebrated Cintra Valley in Portugal, which Bryon considered the most delicious locality in Europe; but where can be found those mountains and classic beauty, those velvety tints, that soft and balmy atmosphere, that moderate temperature, notwithstanding the vicinity of the torrid zone, that charm impossible to define?"

And of its climate W. Vignal writes (*British Medical Journal*, 1893): "I do not think it possible to find anywhere a more perfect climate, and as far as I know there is none comparable to it."

From May to August there is no rainfall at Orotava, and the annual precipitation is 13 inches. The average number of rainy days is 51; and the rain falls most frequently at night. The temperature of the sea water is lowest in March, 64°; and highest in July, 68° (Solly, "Medical Climatology").

In comparing the Canaries with Madeira, the former have in common with the latter the equability of climate, but they have a slightly higher temperature and are considerably drier, the relative humidity from November to April at Orotava being 64.9 per cent., and at Funchal, Madeira, during the same time, 72 per cent. The Canaries, say Weber and Foster, "have a greater claim as health resorts than Madeira and offer good accommodations, but are much wanting in means of amusement." The accommodations at Las Palmas and Orotava, and at some of the other towns in the islands, are good and abundant. The water-supply at Las Palmas and Orotava is brought from the mountain, and is of good quality. There is no general drainage system, but each hotel has its own private water drainage system; in general, cesspools prevail. The soil is porous and dries rapidly after rain. Zymotic diseases are not common. At Las Palmas quite recently a cold-storage and freezing establishment has been opened, and a building estate developed, with villas suitable for residents and visitors. At present most of the invalids and visitors come from England.

The diseases for which the climate of the Canaries is favorable are incipient phthisis—Las Palmas or the port of Orotava in the winter, and the mountains in the summer,—scrofula, chronic bronchitis, heart diseases and Bright's disease, and rheumatism.

While we have a climate in many respects similar to that of the Canaries, in Southern California, more especially inland, and in some portions of the Southwest, the novelty of the change, the ocean voyage, and the variety and beauty of the scenery of the "fortunate isles" may tempt some invalids to try its mild, sunny climate and pure atmosphere, and enjoy the "*equability* of an island climate combined with the *dryness* of a continental one."

For a more extended account of the Canaries the reader is referred to: "Tenerife and Its Six Satellites," by Olivia M. Stone, 1887; "Madeira and the Canary Islands," by A. Lander Brown, 1896; "The Canaries for Consumptives," by E. Paget Thurstan, 1889; "Climatic Treatment in Grand Canary," by Brian Melland; *The Medical Chronicle*, Manchester, England, 1897; "The Canary Islands as a Health Resort," by John Whitford, 1890; "The Therapy of Ocean Climate," by Albert H. Gihon, M.D.; Transactions of the American Climatological Association, 1889. *Edward O. Otis.*

CANCER. (CLINICAL.)—In the first place it is well to have a clear understanding as to what we mean by the term "cancer." I believe that the time has come when we should give up trying to limit the term "cancer" to tumors of epithelial origin, excluding those arising from connective tissues, though the latter may, and frequently do, equal or even surpass the former in malignancy. There is really no good reason for this distinction, and it is far better to go back to the older use of the word in which cancer included all varieties of malignant tumors, whether carcinoma or sarcoma; the feature of malignancy should really be the determining factor, and not some microscopic distinction in histological structure that is often so finely drawn that the trained pathologist is unable to decide upon the proper classification. At present, though we often are able to give some temporary comfort to a patient with sarcoma by assuring him that his trouble is not cancer, yet, if he happens to be suffering from a subperiosteal sarcoma of the femur and knew that of sixty-eight cases treated by the most extensive operation, viz., hip-joint, or very high amputation, but one was known to have been cured, he might readily wish to exchange places with his neighbor who has a well-marked cancer of the lip with one chance in two of being cured by a small operation.

General Consideration.—While the problem of the etiology of malignant disease comes hardly within the province of this article, it is so intimately connected with the clinical history and rational treatment that a few lines may not be out of place.

As having a more or less direct and very important bearing upon the etiology of cancer, should be mentioned (1) its local distribution; (2) its rapid increase during recent years; and (3) the influence of injury as a direct or predisposing factor in its development.

Local Distribution.—Much has been written in proof of the fact that cancer is far more prevalent in some countries than in others, and in some localities in the same countries than in others, but we are more deeply indebted to Mr. Alfred Haviland than to any other writer for accurate and detailed data concerning this varied distribution.

In 1868, in his first paper, read before the Medical Society of London, on the "Geographical Distribution of Cancer among Females throughout England and Wales during 1851–60," he found that 4.33 cases of cancer occurred in every 10,000 females and only 1.94 in every 10,000 males.

In a recent paper (1899) he has found in the period 1881–90, 7.30 cases in every 10,000 females and 4.30 cases in every 10,000 males. That is, the number of cases in females has nearly doubled and the number in males has more than doubled during a period of thirty years.

Roswell Park, of Buffalo, is a firm believer in the increase of cancer, and in a recent paper he makes the statement that in England and Wales from 1840 to 1890 the death rate has increased four or five times, and he further adds: "A careful study of all these tables permits one to make the following startling prophecy: If for the next ten years the relative death rates are maintained, we shall find that in ten years from now, viz., in 1909, there will be more deaths in New York State from cancer than from consumption, smallpox, and typhoid fever combined."

It is true certain writers, among the ablest of whom may be mentioned Newsholme,* attempt to show that this increase is more apparent than real, and may be largely explained by greater accuracy in diagnosis at present than in preceding years, and in the increasing number of autopsies. I prefer to believe with Mitchell Banks, in his recent and most valuable lectures on "Cancer of the Breast" † that these explanations account for but a very small part of the increase, and that it is as real as it is alarming.

Haviland's latest conclusions upon the local distribution of cancer, based upon the most careful study of more than a third of a century, are as follows:

"1. That districts having the highest death rates from cancer among females were invariably associated with seasonably flooded areas traversed by, or in close propinquity to, seasonably flooded rivers.

"2. That geologically these high mortality districts were characterized by alluviums and subsoils of clays of every variety of formation.

"3. That districts having the lowest mortality were situated on an elevated land where drainage was good.

"4. That geologically these low-mortality districts were characterized by the oldest paleozoic rocks, especially those of the carboniferous limestone period."

This question that Haviland first brought before the medical public in 1868, "How is it that limestones are always associated in England and Wales with the lowest mortality from cancer and *flooded clays* with the highest?" he is still unable to answer, but when it is answered, he believes much light will fall upon the cause of cancer.

The most complete of recent statistics on cancer are found in the elaborate paper of G. Heiman, of Berlin (*Archiv f. klin. Chir.*, Bd. 57 and 58). These statistics confirm the view that cancer is rapidly increasing.

In the year 1877 there were 6,971 deaths from cancer in Prussia, and in the year 1896 17,643, an increase of 153 per cent. Of 10,000 living in 1877 the mortality from cancer was 2.66, while in 1896 it was 5.53.

Heiman has also made separate statistics for the mortality in cities and the country districts: In 1876 in the cities it was 3.62, in the country, 1.82; in 1881 in the cities it was 4.70, in the country, 2.25; in 1886 in the cities it was 5.71, in the country, 6.43; in 1891 in the cities it was 6.43, in the country, 3.24; in 1896 in the cities it was 7.9, in the country, 3.8.

In still further confirmation of the opinion that cancer is increasing may be cited the mortality records of the Mutual Life Insurance Company of New York, as recently quoted by Oliver, London *Lancet*, November 10th, 1900, p. 1341. The statistics show that in 1879 the percentage of deaths from cancer in patients between fifty and seventy years of age was 4.23; in 1889 it was 6.22, and in 1898, 7.59. In further support of this view, Oliver refers to the statistics of the Scottish Widows' Fund, collected by Claude Muirhead. Between 1815 and 1845 the deaths from cancer were .93 per cent. of the whole number; from 1845 to 1852, .72 per cent.; from 1852 to 1859, 2.87 per cent.; from 1859 to 1867, 3 per cent.; from 1867 to 1873, 4.56 per cent.; from 1873 to 1880, 4.34 per cent.; from 1880 to 1887, 5.23 per cent. Muirhead states that, "allowing for greater accuracy in returns, the number of deaths from this cause has increased enormously."

As to the question of heredity, the statistics of the Scottish Widows' Fund show that 9.5 per cent. gave a history of malignant disease in parents.

The difference between the prevalence of cancer in the city and the country is very striking. This steady increase cannot, I think, be explained by increasing skill in diagnosis.

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* Practitioner, London, April, 1899. † *Loc. cit.*, March 10th, 1900.

As Mitchell Banks has pointed out, in 1861 such men as Miller, Syme, Spencer, and Wilson, the leading surgical teachers of Edinburgh, were the equal of any of the present day in diagnostic skill as regards both external and internal cancer.

The Parasitic or Infectious Theory of the Origin of Cancer.—The embryonic theory of Cohnheim which has long been accepted by most pathologists falls far short of explaining many important points in the etiology of cancer, and must, I believe, soon be abandoned. While the result of the long and patient investigations of Russell, Plimmer, and San Felice and Leopold in Europe, and of Park and Gaylord in this country, have not yet absolutely demonstrated that cancer is of a parasitic origin, we are, according to Park, justified "at least in maintaining that some cancers are of such origin." And if it can be demonstrated that some are, there is strong probability that all are. The almost constant presence of these peculiar bodies in all cancers including sarcoma, and especially in the advancing and growing borders, as proven by Plimmer, whether they prove to be blastomyces or protozoa, furnishes strong presumptive evidence that they may have some bearing upon the causation of the tumor. Now that pure cultures of these organisms have at last been made, and that actual carcinoma has been experimentally produced in animals by these cultures, it would seem that the parasitic or infectious theory of cancer has passed beyond the stage of ridicule and is worthy of serious consideration. It explains far better than any other theory the geographical differences in the prevalence of cancer, as well as the increasing mortality. Furthermore, cancer closely resembles other diseases, *e.g.*, tuberculosis and syphilis, which are known to be of infectious origin. If we admit the origin it is easy to explain the various types of the disease, from the slow-growing epithelioma of the face to the rapidly fatal sarcoma of the testis or orbit, by supposing that the infectious agent, like the malarial organism, varies as to its morphology within wide limits, different types of the germ (or different conditions) causing very different clinical manifestations. The whole clinical course of cancer is strikingly suggestive of an infectious disease. The question of the infectious or parasitic nature of cancer has very recently and ably been discussed by Mitchell Banks in the last of his three lectures on "Cancer of the Breast" (*loc. cit.*). He calls attention to the fact that the first notable step in advance was made by W. Russell, of Edinburgh, in 1890, whose paper on "Characteristic Organisms of Cancer" excited profound interest. These so-called "fuchsin bodies" of Russell, which he described as both intracellular and extracellular, were even then regarded by Russell himself as blastomycetes, a variety of saccharomycetes or yeasts. While the great majority of pathologists in different countries have been of the opinion that these bodies described by Russell are not "characteristic organisms of cancer" but rather certain forms of cell degeneration, there have always been notable exceptions on the other side, and the question has remained an open one until at present the weight of evidence is strongly in favor of regarding them as separate organisms.

In 1892, Soudakewitch, of Kieff, and Armand and Ruffer, of London, published papers describing bodies similar to those described by Russell. Specimens of these bodies were carefully examined by the distinguished Metchnikoff, who believed them to be "parasitic protozoa." The original opinion of Russell that they are blastomycetes has recently been revived and strongly advocated by the well-known Italian investigators, San Felice and Roncali. These bodies are of various size, estimated by Plimmer at from .004 to .04 mm., and they may be stained in several different ways. The Ehrlich B triple stain or the Ehrlich acid hæmatoxylin, in distilled water rendered faintly alkaline with lithium carbonate, may be mentioned as most satisfactory.

The latest researches of Leopold [*] along the same lines are strongly confirmatory of the work of Plimmer and San Felice. Leopold's paper is the result of diligent labor extending over many years. He has examined several hundred carcinomata of numerous localities, excluding as far as possible ulcerating tumors. Leopold found the organisms variously described by others, and believes them to be blastomycetes. In twenty cases he tried to cultivate blastomycetes from the carcinomatous tissue and met with greater success than any of his predecessors. In four cases he obtained pure cultures from malignant tumors. In attempting to inoculate animals he had three positive successes. A curious fact was observed that, while the culture of blastomycetes had been obtained from carcinomatous tissue, the tumors in two instances resulting from inoculation were sarcomatous. This fact, if further confirmed, together with the fact that hereditary malignant disease not infrequently takes the form of carcinoma in some member of a family and of sarcoma in others, would go to show that the etiological relationship is exceedingly close.

Symptomatology and Treatment of Cancer.

Diagnosis.—There is no department in surgery in which there is greater need of large clinical experience and well-trained powers of observation than in the diagnosis of malignant tumors. In every suspicious case a careful history of the patient should be obtained before a diagnosis is attempted. Among the most important points to be elicited may be mentioned: hereditary influence, the anatomical situation of the tumor, its duration, and the rapidity of its growth. Too much stress should not be laid upon the apparent duration of the tumor, inasmuch as in not a few instances it may have existed for a considerable time before it was observed by the patient. The situation of the tumor is often of great aid in diagnosis. If it is first observed in the glands—for example, the cervical, axillary, or inguinal—there is a strong probability that it may be a secondary growth, and careful search should be made for a primary growth in the mouth or throat, the breast, rectum, or pelvic organs, or even the extremities. I have myself observed a large fungating sarcoma of the groin, supposed to originate in the inguinal glands, and although the patient stated that he had never had any swelling in the leg or foot, careful inquiry showed that two years previously he had had a small ulcerated area upon the ball of the foot, produced by the irritation of a projecting nail in the shoe. This apparently healed, but from time to time there was a recurrent ulceration and a slight discharge. A small indurated area remained, but gave such slight symptoms that the patient never thought of connecting it with the trouble in the groin. The patient soon died of general metastases. At autopsy the area in the ball of the foot was excised and found to be the primary pigmented sarcoma.

On examining the tumor itself, the surrounding tissue should be carefully palpated in order to determine its relation to the skin, the muscles, or the underlying bony structures. The size of the tumor, and the rapidity of growth, are very important points to be noted. Pain and tenderness, while far less important than many writers have led us to believe, should nevertheless be always noted. While in most cases of malignant disease, especially in carcinoma of the breast, pain is rarely present in the early stages, it is seldom absent after the tumor has become well developed. Pain is much more important in the diagnosis of recurrent than in that of primary tumors. In many cases of recurrent cancer the patient based her suspicion solely upon the peculiar stinging pain resembling that which she had experienced during the existence of the primary tumor, and in almost every case I have found these suspicions well founded. Therefore, in suspected recurrent cancer, one cannot be too careful in considering the symptom of pain. In some localities the primary tumor naturally is attended with marked pain. This is especially the case in malignant tumors originating in the spine or in the pelvic bones.

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[*] Leopold, "Researches as to the Etiology of Carcinoma and Pathogenic Blastomycetes." Archiv f. Gynäkologie, vol. lxi., No. 1.

In most cases of sarcoma of the ilium, sacrum, or ischium, the first symptom is a severe neuralgia of the crural or sciatic nerves, and cancer is seldom suspected for a considerable time.

Tenderness.—Tenderness is a very important diagnostic sign, especially from its negative value. It often enables us to distinguish between a malignant and an inflammatory tumor. Tenderness may be said to be practically absent in most malignant tumors.

Palpation.—By this means may be determined the consistence of the tumor, its mobility, the presence or absence of pulsation, tenderness, or crepitation. Mobility is a valuable guide in differentiating sarcoma from carcinoma, or carcinoma from a benign tumor. Inasmuch as carcinoma has a tendency to infiltrate the surrounding tissues, sarcoma will be found to be much more freely movable than carcinoma.

General Symptoms.—Careful inquiry should be made as to the patient's general health, his mode of living and his habits, and a thorough physical examination should be the rule in all cases. Also the age of the patient should invariably be ascertained, for not infrequently this alone will enable one to diagnosticate a malignant from a benign growth. While carcinoma occasionally occurs under the age of thirty years, such cases are extremely rare. Loss of weight, if of considerable amount and progressive, is of much significance. A general physical examination often enables one to avoid a useless operation, by disclosing the fact that the patient is already suffering from metastatic deposits in the lung, liver, or other localities, although the primary growth may be readily removable. The local examination of the tumor itself should be thorough and systematic; one should note its color, its size, the condition of the overlying skin, whether thickened, adherent, or dimpled as in carcinoma of the breast, or greatly thinned out as in a rapidly growing sarcoma, the presence or absence of ulceration, and the amount and character of the discharge, if present. The consistence of the tumor throws much light upon the diagnosis. If it is hard and indurated, with other signs of malignancy, the diagnosis points strongly toward carcinoma, while if soft and semifluctuating, the probabilities are much in favor of sarcoma.

Exploratory incisions, or the removal of specimens for microscopical examination by means of the Mixter punch, under cocaine, have been frequently resorted to, and are still much used by many surgeons. While there is much to be said in favor of this method of confirming a doubtful diagnosis, there are strong reasons for restricting its use within the narrowest limits. I believe that the cutting into a highly vascular and soft malignant tumor, or even the removal of a portion with the Mixter punch, is attended with considerable risk of disseminating tumor cells throughout the body and producing generalization of the disease. I have personally observed a number of cases in which this method was used, develop metastases within a few months after exploration, so that I have given up exploratory incisions, except in cases in which it seems absolutely necessary. In the case of a small, doubtful tumor of the breast it is far better to remove the entire growth than to cut into it and remove a small portion for the purpose of microscopical examination. In a case of suspected sarcoma of the femur, instead of removing a portion prior to operation, I have adopted the plan of preparing the patients for a hip-joint amputation, then—after the tourniquet has been applied—cutting into the tumor to confirm the diagnosis prior to amputation.

Prognosis.—The prognosis in cancer depends very largely upon the locality of the primary growth. It also depends greatly upon the rapidity of growth prior to operation. This point is very well brought out by the statistics of cancer of the breast by Dr. J. Collins Warren, of Boston, which show that in the successful cases the tumor had existed prior to operation for a longer time than in the unsuccessful. In other words, the more rapid the growth of the tumor the less the probabilities of curing it by operation. The prognosis has improved remarkably within recent years by reason of earlier diagnosis and earlier operation, as well as from improved technique. Yet this great improvement has been insufficient to offset the increase of the mortality, on account of the rapid and progressive increase in the number of patients afflicted with cancer. In certain regions the prognosis is still absolutely bad; for example, periosteal sarcoma of the femur which, according to the latest statistics of Butlin, show but one cure in sixty-eight cases treated by amputation at or near the hip-joint, and cancer of the stomach or larynx, in which the percentage of cures is extremely small. On the other hand, if we are dealing with cancer of the breast or lip, the extensive operations and improved technique of the present day offer the patient about one chance in three for being cured. The age of the patient also has an important bearing upon the prognosis. It may be laid down as a general rule, particularly true in carcinoma, that the younger the patient the more rapid the course, and the worse the prognosis. In the very aged, while perhaps the probability of a cure may not be greatly increased, the progress of the disease will be very much slower. I have observed a cancer of the breast in a woman aged ninety-four years, of eight years' duration. During the two years of my observation there was little change in the size or appearance of the growth, and the general health of the patient was but little affected. Early and repeated recurrences, while making the prognosis much worse, should not cause the surgeon to give up all hope of a cure, and if the tumors are anatomically removable, he should continue to operate.

Treatment.—*General Treatment.*—While the majority of the profession believe that drugs have little or no influence upon the progress of cancer, there have been many remedies that, from time to time, have enjoyed much favor in the treatment of the disease. There is no inherent or *a priori* reason why certain drugs should not have an inhibitory influence upon the growth of malignant tumors, especially if these tumors prove to be due, as many of us believe, to an infectious agent. Therefore, we should not deny the possibility of the existence of such a drug, or refuse to give all a fair trial. The statement of Senn that "no kind of internal medication has any influence whatever in limiting tumor growth, much less in causing the disappearance of the tumor," is not, I believe, in harmony with the facts. There are certainly well-authenticated cases of sarcoma, especially of the skin, in which the disease has been clearly retarded by the use of large doses of arsenic; there are likewise well-authenticated cases of sarcoma and even of carcinoma, that have shown decided improvement under mercurials and iodides. I have personally observed more than one such case in which the diagnosis was confirmed by microscopical examination. In one case, a carcinoma of the breast, the improvement was so marked under large doses of iodine that the diagnosis of syphilis seemed clearly correct; after a time the improvement ceased and exploratory operation showed the growth to be a typical carcinoma.

Local Treatment.—This includes operative treatment as well as removal by caustics, electrolysis, parenchymatous injections, and the injections of the toxins of erysipelas, which produce both local and systemic action, though the local predominates.

Operative Treatment.—Free and thorough excision of cancerous tumors with the knife is the only method of treatment that should be considered in cases in which it is possible completely to remove the disease. By removal we mean not only removal of the tumor itself, but of all the neighboring lymph glands, together with the connecting lymphatics. A careful study of recurrent cancer shows that in by far the largest proportion of cases the return takes place in the region of the skin or cicatrix. Therefore, if we expect to improve the results, we must remove wider areas of skin in the future than has been our custom in the past.

Limitations of Operative Treatment of Cancer. Cancer is unquestionably a local disease at its origin and during the period of its early development, and if treated by thorough removal at this period can, in the majority of cases, be cured. The difficulty, however, in operating at this time lies in the fact that the tumor itself is not always discovered until the disease has already infected the neighboring glands, and in other cases when discovered, the patient refuses an early operation. The curability of cancer depends largely upon our ability, anatomically and surgically, to remove the invaded area, together with a sufficient amount of healthy tissue on all sides. From a clinical standpoint we must admit that it is impossible to cure all cases, but even with the limitations which I have mentioned as regards early diagnosis and the difficulties in persuading patients to submit to early operation, we are still able to cure a very large number of patients and materially to prolong and render more bearable life in many others. I believe with Banks and Shield, that the pendulum has swung too far in the direction of operative treatment for cancer, especially in the later stages of the disease. We are not likely to err in the direction of too extensive operations in the early stages, and, indeed, there is reason to believe that our operations are generally not extensive enough in such cases; but I have seen many cases of advanced recurrent cancer subjected to operation, in which there was little or no prospect either of curing the patient or of rendering the disease less distressing. It is natural that surgeons should not always agree as to the exact classification of operable and inoperable cases, yet it is possible for us to lay down certain general rules which may be of help in deciding this difficult question. There will always be surgeons who will operate only upon cases in which there is a high probability of final success, and there will be others who will continue to operate when there is practically no hope of effecting a cure, or of completely removing the disease, even though the operation itself may be attended with the gravest risk to the life of the patient. Partial operations in which there are large infected areas left behind, instead of decreasing, frequently increase the rapidity of growth. Watson Cheyne does not believe that we should refuse operation unless early recurrence is very highly probable, or unless operation means almost certain death.

My own feeling is that often in persuading ourselves that there is a bare possibility of curing the disease in these advanced cases, we are apt to forget that the high mortality and the very small proportion of cures cannot but have a great influence upon the laity in destroying their confidence in all operations for cancer, and thus prevent many patients suffering from cancer in the early and operable stage from consulting a surgeon or consenting to operation at a time when the prospect of cure is good. Operations, therefore, I think, should not be advised unless there is strong probability of being able to remove the entire disease. This does not mean that we should not in certain special cases remove foul, fungating masses, when thereby we may be able to add greatly to the comfort of the patient, although there is no prospect of prolonging life.

General Considerations.

Sex.—Of 7,878 cases of primary neoplasm collected by Williams the proportion of males and females was 1 to 1.7. According to statistics covering years between 1872 and 1898, cancers of all kinds show a proportion of 1 male to 2.29 females. Comparing the mortality of cancer with that of all other diseases, we find that among males we have 1 death from cancer to 100 deaths from all other diseases; while among females we have 1 death from cancer to 49 deaths from other causes. The statistics of the year 1889 show that of every 21 males who reach the age of 35 years, 1 dies from cancer; while in females who reach the age of 35 years, 1 in 12 dies of cancer. Williams' statistics show, however, that the relative difference in the mortality of the (two) sexes is gradually decreasing, the records for 1851 showing the ratio to be 1 male to every 2.2 females, whereas, in 1896, it had diminished to 1 male to every 1.4 females. Curiously, in certain localities this ratio is reversed. For example, in New South Wales and New Zealand the mortality is greater in males than in females.

Age.—Of 941 consecutive cases of malignant tumors observed by Williams, there were only 25 cases under the age of 25 years.

Williams believes that a considerable number of malignant neoplasms are of congenital origin, and that in some instances these are multiple from the start. I have personally observed 1 case of a very large multiple round-celled sarcoma in an infant 6 months of age, in which the multiple growths were noted soon after birth. The disease ran a very rapid course.

Under the age of puberty carcinoma is so rare as to be practically unknown. The rectum is the most favorable site for malignant epithelial disease occurring before the age of 30. The type of disease is either carcinoma or malignant adenoma. About 20 such cases have been reported under the age of 30. R. de Bovis (*Revue de Chirurgie*, Juin, 1900) found 35 cases of cancer of the large intestine (exclusive of the rectum) under the age of 30, out of a total of 400 cases. Of 500 cases of mammary cancer observed by Williams, the youngest patient was 24 years of age. Of 1,622 cases collected by Gross, the youngest patient was 22 years.

In the uterus the disease may occur somewhat earlier in life than in the breast, although the difference is not great. Of 500 cases collected by Williams, it occurred once in an individual 22¼ years old; while out of 3,385 cases collected by Boussereau, it occurred in 2 under the age of 20 years; and 1 authentic case has been reported at the age of 17 years.

It is a well-known and somewhat striking fact that cancer is seldom seen in the very aged. Williams states that of 1,087 centenarians only 5 died of cancer, giving a proportion of 1 in 217; while of 202 individuals between 90 and 100 years of age, not a single one died of cancer. Of 500 cases of cancer of the uterus, the oldest was aged 83 years. The oldest individual with cancer of the breast observed by Williams was 84 years. I have personally observed cancer of the breast in a woman aged 94 years. The disease had existed for six years and the progress was extremely slow. It may be stated that the average age of women with mammary cancer is 48, and with uterine cancer 44, with cancer of the tongue and mouth 50, of the lip 51.6, of the rectum 50.7, of the stomach 40.5. The maximum period of frequency in the female is 45.55, in the male 55.65 years.

Geographical Distribution.—The mortality from cancer differs very greatly according to locality, also according to the period covered by the statistics, the mortality showing a general increase, as has already been stated, all over the world during the past half-century. The mortality for 1890 was 7.9 per cent. for Boston; 6.2 per cent. for New York; 4.8 per cent. for Brooklyn. Fifty large American cities, in 1888, showed a cancer mortality of 7.9 per cent., of which 5.1 per cent. were females, 2.8 per cent. males. Comparing these statistics with European cities, we have for London, 6.8 per cent. in 1881 to 1890; for Paris, 10.4 per cent. in 1886 to 1891; for Lyons, 16.3 per cent. in 1892.

Heredity.—The influence of heredity upon the etiology of malignant disease is a question about which there is still little uniformity of opinion. However much authorities may differ as to the amount of influence attributable to heredity, it is impossible to deny that there is some influence. Numerous cases have been cited to show that in certain families this influence has been very striking. Williams observed a patient, aged 53, suffering from uterine cancer, and whose maternal grandmother, mother, mother's two sisters, and patient's two sisters all died of cancer of the uterus. The Bonaparte family is another striking illustration of the influence of heredity. Napoleon's father, brother Lucien, and two sisters, died of cancer of the stomach. Manichow reports 23 families in which intermarriage had been frequent, showing 69 cases of cancer, of which 57 occurred in the stomach. The tendency of hereditary cancer to attack the same organ in different members of the family is another remarkable peculiarity of this mysterious influence. A case was cited by Williams, in which the mother and five daughters all died of cancer of the left breast. I have myself reported two cases of sarcoma of the left breast occurring in two sisters, appearing at the same age and both immediately following trauma. Williams believes that these peculiarities associated with heredity point to intrinsic rather than extrinsic causes of the disease. It seems to me that such a conclusion is hardly warranted by the facts. We certainly can get very little light upon the vexed question of etiology from what we know of hereditary influence.

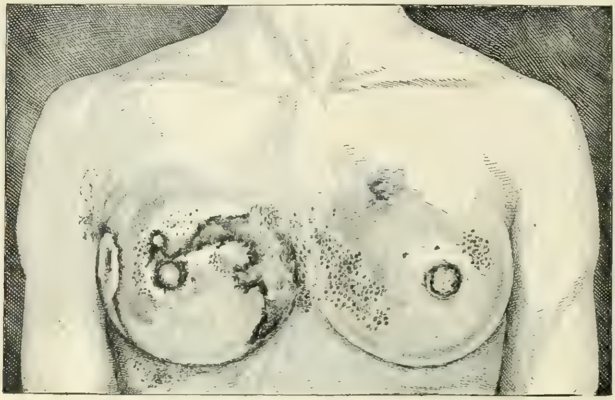

FIG. 1098.—"Squirrhe Disseminée." Acute Traumatic Carcinoma.

As to the frequency with which hereditary influence has been observed, statistics differ. Williams found a family history of cancer in 24.2 per cent. of 136 cases of cancer of the breast; while of 209 men suffering from cancer of various organs, a history of heredity was found in but 11 per cent. Selecting only those cases in which there was a history of cancer in parents, the percentage is 8. A very curious fact has been noted, namely, that a patient is capable of transmitting this hereditary influence to offspring while latent, or long before any evidence has been visible in the patient herself. For example, Broca's famous case of Mme. Z., who had four daughters, all of whom died of cancer, and yet they were born from fifteen to thirty years before the mother herself contracted the disease. It has further been noted that hereditary influence is more often transmitted to the female than to the male line. For example, of 19 daughters and granddaughters of Mme. Z. that lived to be 30 years of age, 14 died of cancer, whereas of 17 males only 1 died of cancer.

Cancer is far more frequently seen in persons of robust health than in thin, weakly individuals. Williams is inclined to attribute considerable weight to the opinion that the increase in cancer may possibly be due to the fact that during the last fifty years the standard of living has become so much higher, much larger quantities of animal food being consumed now than formerly.

CANCER OF SPECIAL REGIONS.

CANCER OF THE BREAST.—Carcinoma of the breast rarely occurs in women under the age of 30, and one seldom sees it until after the age of 35. The average age at which it appears, as given by Gross, is 48 years. The first thing the patient usually notices is a lump in the breast, without any history of antecedent pain. The growth does not change materially in size for a number of months, and it being nearly or quite painless, the patient does not regard it of serious importance. Later on, occasional sharp twinges of pain may appear. The pain is always at first intermittent, and does not become dull and steady until the later stages of the disease. The family history of the patient, as well as the previous personal history, is of great importance.

Heredity is found in about 21 per cent. of all cases. A considerable number of patients give a history of local injury, and the more one studies the malignant tumors from a clinical standpoint, the more importance does one attach to the influence of antecedent injury in the etiology of cancer. MacWilliams* states that in 100 consecutive cases operated upon at the Presbyterian Hospital of New York, 44 gave a history of antecedent injury.

Inflammatory trouble often precedes the development of cancer of the breast, and, no doubt, likewise has some influence on its causation. Although many—perhaps the majority—of surgeons refuse to believe that there is any direct etiological relationship between trauma or chronic inflammation and cancer, the clinical fact remains that these conditions are very frequently associated with the development of cancer, and although we are at present unable entirely to explain this relationship, the facts must have due weight in making our diagnosis. Antecedent injury in carcinoma of the breast is variously estimated at from 12 to 40 per cent. In sarcoma the percentage is much higher. Nearly all the cases of sarcoma of the breast that I have personally observed have given a distinct history of local injury. It has been the custom of most writers to minimize the patients' statements with reference to having received blows or knocks upon the breast, the reasons given being, first, that only a certain percentage of patients give this history, and second, that every woman probably receives similar blows without the development of cancer, and that, therefore, they cannot have an important bearing on the disease. If we could know the exact facts, I believe that the percentage of cases in which injury has been noted is far smaller than the actual percentage in which it has occurred, the reason being that many patients have forgotten the antecedent injury. The fact that many women who receive blows upon the breast do not develop cancer is no more argument against the etiological relationship of trauma, than it would be to cite the fact that many patients are exposed to the diphtheria bacillus and do not contract the disease, as an argument against the relationship between the bacillus and the disease in persons who did contract it.

Malignant disease of the breast may be either acute or chronic. *Acute miliary carcinosis* or *squirrhe disseminée* is exceedingly rare, and but few cases have been reported. I have personally observed one case occurring in a woman of 38 years, immediately following a blow. The disease ran a very rapid course, spreading quickly to the other breast, involving the entire skin and the anterior portion of the thorax, causing death in about nine months. Only 2 cases of this variety were observed by Williams in 170. Carcinoma en cuirasse is also comparatively rare, only 3 cases having been observed by

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* Medical News, April 28th, 1898.

Williams in 170. Carcinoma en cuirasse is not a special type of cancer, but derives its name from the fact that the superficial or skin lymphatics are early and extensively involved. The opinion held by some writers, that the disease is limited to the skin, is probably erroneous. The primary focus is in the breast, and the contiguous lymphatics are involved at an early period.

The *chronic* form of carcinoma of the breast includes those cases in which the disease has a duration of five years or more. In Williams' list of 170 cases 31 were of the chronic form. Of these, 14 cases had a duration of from 5 to 10 years; 6 a duration of from 10 to 15 years; 2 a duration of from 15 to 20 years; and 1 a duration of from 20 to 25 years.

One case of undoubted breast cancer has been reported in which the disease lasted for over thirty years.

Melanotic growths are exceedingly rare in the breast, especially in the female. Williams' table of 2,397 cases of primary carcinoma of the breast does not contain a single example of melanotic carcinoma; while in 100 cases of cancer of the male breast there were 3 of the melanotic type. I have personally observed 1 case of melanotic cancer of the female breast. The history of the case is as follows:

Melanotic Sarcoma of the Breast.—Mrs. F., aged 44, married, with four children, good family history, had inflammation of the right breast ten years ago. Shortly after this she noticed a small lump in the region of the nipple, but not attached to the skin. This remained comparatively stationary for nine years. At the end of this time the nipple became slightly retracted, and a small lump appeared in the opposite breast, which was of bluish color and attached to the skin. The first operation was performed by Dr. Abbe, of St. Luke's Hospital, on the 19th of July, 1897. Both tumors were removed, together with two other smaller ones on the outer aspect of the left arm. When seen by myself, on August 29th, 1898, there was an area four by five inches in extent, of local recurrence, together with numerous small, dark-colored nodules scattered through the skin of the abdomen.

Paget's Disease of the Nipple.—Shield, who has made a careful study of this disease, believes "superficial carcinoma of the skin" a better term. The disease is rare and the diagnosis not infrequently difficult. It is almost invariably, although not certainly, followed by carcinoma of the breast itself. As regards the treatment of this disease, I am thoroughly convinced that nothing short of a very radical operation (namely, complete removal of the breast and axillary glands) should be performed. Shield states that he has never known a genuine case of Paget's disease cured by local remedies. I have personally observed two cases of Paget's disease; in the first of these I operated upon September 13th, 1897, and the entire breast, together with the axillary glands, was removed. The patient has remained well up to the present time, three and a half years after the operation. The second case refused operation, and one year later the disease had involved the breast so extensively that operation was impossible.

Cancer of the breast occasionally may co-exist with sarcoma of other organs. Roger Williams has collected 11 such cases. I have personally seen one. The patient was a woman, 53 years of age. In July, 1896, I operated for a recurrent carcinoma of the breast; in September, 1896, I removed from the same patient a round-celled sarcoma the size of an egg, from the submaxillary region, on the same side. The disease quickly recurred, and in a few months proved fatal.

Diagnosis.—*Age.* Cancer of the breast is extremely rare under the age of 30, and few cases have been observed under the age of 35. The average is estimated by Gross as 48 years.

The clinical history of the ordinary case would be something as follows: The patient will be in middle life, probably married. Eighty-eight per cent. of the cases collected by Gross occurred in women who were or had been married. There will be a history of slight pain, or occasional stinging sensations hardly severe enough to be characterized as pain. There is seldom dull or constant aching in the early stages of the disease. In many instances the patient discovers the lump while bathing, before the advent of pain. Too much stress should not be laid upon pain, inasmuch as many cases of cancer of the breast become comparatively far advanced before they produce appreciable pain. Gross states that "carcinoma of the breast begins as a small, painless nodule." In about one-third to one-half of the cases the patients give a history of having received some injury to the breast at varying intervals of time prior to the discovery of the tumor. Previous inflammatory trouble or antecedent injury is of great importance and should be carefully inquired into. For notwithstanding the circumstance that many refuse to admit that there is an etiological relationship between trauma and cancer, the clinical fact remains that these conditions are very frequently associated with the development of malignant disease; and, although we may not at present be prepared to offer a satisfactory explanation, the facts must have due weight in our efforts to establish the diagnosis.

The frequency of histories of previous trauma in cancer of the breast varies from 12 to 46 per cent. in the statistics of different writers. A careful physical examination will enable us in most cases to make a diagnosis; and in making this examination the fingers should be applied flat against the parts and should not be used as in pinching. In carcinoma of the breast the tumor is generally very hard, no matter how small it may be. It is usually found somewhere in the periphery of the breast, and is, even in the early stages, much more fixed to the surrounding breast tissue than are benign growths. In about half of the cases there will be found a retraction of the nipple, although I believe that the diagnosis should be made in most cases before this sign has appeared. The condition of the skin is of very great importance and is of great help

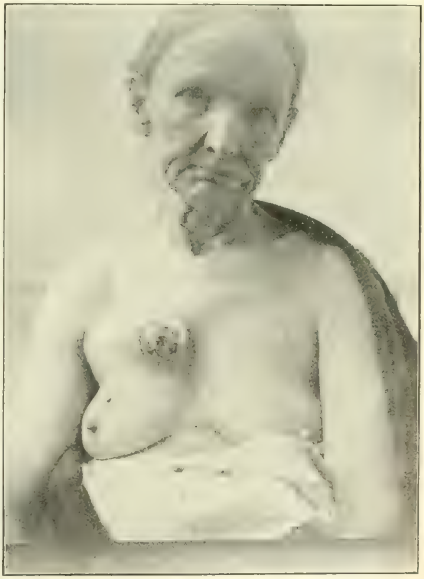

FIG. 1099.—Carcinoma of the Breast.

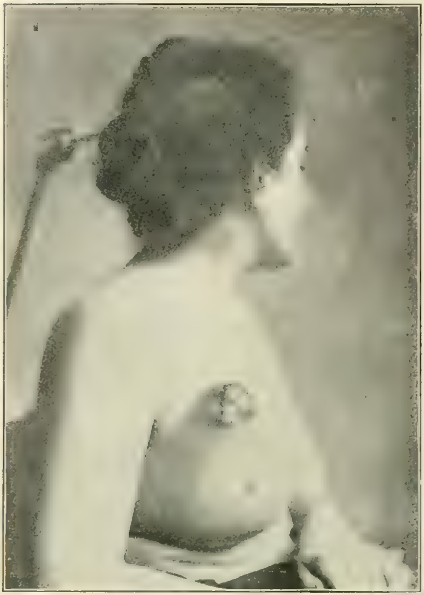

FIG. 1100.

in determining the diagnosis. The peculiar condition, known as "dimpling of the skin" is caused by the contracting of the fibrous tissue lying between the skin and the gland tissue. In the great majority of cases the skin is obviously dimpled. Shield states that there is no sign of more vital importance than this. Even when the skin did not appear dimpled, I have seen cases in which the dimpling could be easily brought out by slightly pinching a considerable area of skin overlying the tumor. Examination of the axilla should always be made, although the absence of enlarged glands would not justify us in excluding carcinoma. The axillary glands are palpably enlarged in about 50 per cent. of the cases. The tumors most likely to be mistaken for carcinoma are fibro-adenoma, cyst-adenoma, fibroma, sarcoma, chronic inflammatory and tuberculous disease. Fibro-adenoma occurs, as a rule, in younger individuals. Of 63 collected by Shield, 45 occurred before the age of 40. This variety of tumor more frequently occurs in single than in married subjects, a fact just the reverse of that found in cancer. The age of the patient and the absence of the characteristic symptoms and signs already noted with reference to cancer enable us to make a diagnosis in most cases. In certain cases, however, it is impossible absolutely to be sure whether the tumor is malignant. However, the plan advocated by some surgeons in such an event, to cut out a portion of the growth under cocaine or with a tumor punch for examination, is hardly to be recommended. The better way is to prepare the patient for a complete operation, first remove the tumor, and if the surgeon is not able to determine whether or not it is malignant on examination of a gross section, a frozen section might be made and examined. In very few cases will this be necessary.

Results of Operative Treatment.—The improvement in results of the operative treatment of cancer is nowhere more manifest than in cancer of the breast. The gradual and, as it were, painful evolution of modern methods from the incomplete operations of a few years ago has been very clearly shown by Sir W. Mitchell Banks in his recent Lettsomian Lectures on "Practical Observations on Cancer of the Breast." * He states that in 1862 operations for cancer of the breast consisted in local removal of the tumor of the most imperfect description. If any glands were affected, this was a sufficient bar to any operation. In 1867 Mr. C. H. Moore wrote what is now an almost historic paper on "Inadequate Operation in Cancer," which set a great many minds thinking, inasmuch as it was "a revolt against constituted authority." Banks' paper, "A Plea for the More Extensive Removal of Cancerous Growths," was published in 1877, and the classic work of Gross on "Tumors of the Mammary Gland" in 1880, or three years later. The works of Moore and Banks and Gross were slow in being accepted. Banks again, in 1882, in a paper read before the British Medical Association, said: "Surgeons, as a rule, do not remove cancers of the breast; they persuade their patients that they do and they almost persuade themselves, but there is always that little bit that they leave behind, and which they fondly hope will not grow because it is such a little bit. Alas, that such little leaven should leaven the whole lump!" Banks made a most urgent appeal in favor of removing the entire breast with a very wide area of skin, but he advocated the removal of all the axillary glands and fat in all cases, whether the glands could be felt or not. As late as 1888 this complete

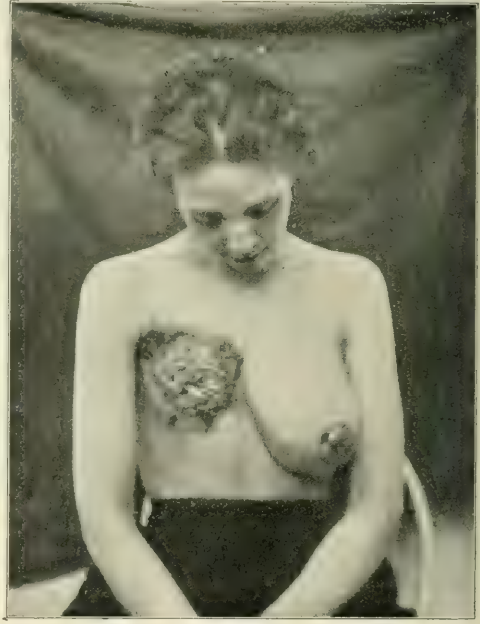

FIG. 1101.—Double Carcinoma of Breast.

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* Lancet, April 7th, 1900.

operation, so long practised and championed by Banks and Gross, was opposed by many of the ablest surgeons of England and America, notably by Butlin and Pick, while Thomas Smith even went so far as to say that patients lived longest who had never been operated upon at all. It is true that the high mortality that followed the operation at this period (16 per cent.) gave some justification for those who were content with the simpler procedure. In spite of all criticism and obstacles Banks and Gross continued to practise as well as to preach the complete operation, until to-day we find that even Butlin himself has not only come over to the complete operation of Banks, but has gone a step further and is now a most enthusiastic advocate of Halsted's operation. While many who advocate the extensive operation of to-day prefer to credit their conversion to the histological researches of Heidenhaim, we must in fairness acknowledge that this great change has been largely due to the earlier clinical works and the superior results of Moore, Banks, and Gross. Banks' statistics are the largest and most complete yet published. He has operated upon 213 cases of cancer of the breast. Of these, 175 have full histories; 67 died of local recurrence, and it is a most remarkable fact that of these 67 cases 17, or 25 per cent., lived from 3 to 13 years; 38 patients were alive and well from 3 to 21 years after operation. Of 108 cases that remained free from local recurrence, 73 lived from 3 to 21 years after operation; 40 from 3 to 6 years; 28 from 7 to 14 years; 28 from 16 to 21 years; 30 died of metastases without local recurrence. Of these it is important to note that 20, or 66 per cent., died from 3 to 14 years after operation.

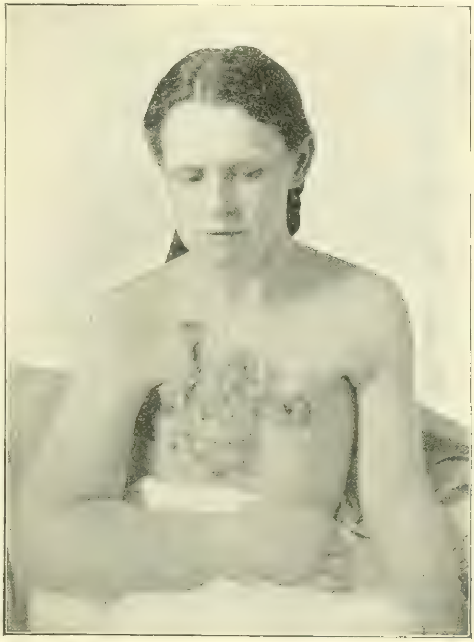

FIG. 1102. Cancer "En Cuirasse."

Adding the cases that died after 3 years from local recurrence to those that died after 3 years from general recurrence, we have 37 patients who, according to the usual reckoning, would have been regarded as cured, yet who really died of recurrence.

Let us then compare the percentage of cases estimated by the usual 3-year basis with the percentage of actual cures of Banks' series of 213 cases (we must exclude 60 operated upon during the last three years and 7 in which only partial operation was performed); we have left 146 cases; 90, or 62.3 per cent., lived beyond 3 years. The careful tracing of the after-history of these 90 cases showed that 38, or 42 per cent., recurred after having passed the 3-year limit. Thus 26 per cent. of the total of 146 cases operated upon more than three years ago recurred after 3 years. This shows the great importance of following up the patients for long periods of time, and makes the statistics of Banks by far the most important data we now possess upon which to base a true estimate of the curative value of surgical treatment of cancer of the breast.

These statistics certainly justify the conclusion of Banks, that "the plan of taking percentages in small numbers of cases ought to be abolished," and, furthermore, that "the 3-year cure system, too, must be abolished if people are to be instructed fairly." The recent statistics of Barker bear out the conclusions of Banks.* Barker's tables contain 100 consecutive cases of breast tumors treated by operation, most carefully traced to final results. Of these, 90 were malignant; 6 died of operation; 33.7 per cent. lived over 3 years and 16 per cent. over 5 years.

In regard to the 3-year limit Barker says: "It is clear that 33 per cent. live more than 3 years after operation, which has been suggested to some surgeons that they should be regarded as permanent cures; but some of the cases (26.9 per cent.) have died most likely of recurrence in all but 1 after an immunity of over 3 years, so that such a presumption is unwarranted."

In one of Barker's cases there was extensive glandular infection and a bad prognosis was given, and yet the patient was well 14 years later.

Cheyne's latest statistics† are among the best that we have. He gives the details of 61 cases operated upon more than three years ago. Excluding the cases not traced and those which died of operation, which I did not do in estimating Banks' percentage, Cheyne has 37 cases remaining, of which 19, or 51 per cent., were alive and well.

Butlin's most recent statistics‡ give 116 cases operated upon between 1880 and 1894. Of these 6 died of operation; 3 were not traced; 51 had local recurrence; 22 had general recurrence; 2 died of other causes within 3 years; 3 died of other causes after 3 years; 29 are alive and well more than 3 years after the operation.

In 1895 Butlin adopted Halsted's method, and of 33 cases up to the end of 1897 had but 1 death. Of these 11 were operated upon more than 3 years ago. Of these 1 died of operation; 3 of recurrence (2 local), and 9, or 70 per cent., were well more than 3 years. These results are brilliant, yet it would be clearly unfair to form an estimate of the value of any operation for cancer on such a small number of cases.

Supraclavicular Glands.—I have not yet been convinced of the wisdom or value of removal of the supraclavicular glands as a routine method in operations for cancer of the breast, and it should be noted that Butlin, who in other respects followed Halsted's method closely, did not remove the supraclavicular glands in any of his cases, and believes with Cheyne that when these glands are removed, the case is hopeless. The statistics of Banks, Cheyne, and Butlin, which equal those of Halsted, would go to show that as good results can be obtained without this step. Until further evidence is forthcoming, I believe we are justified in not removing the supraclavicular glands, unless glands are discovered very high up. Inasmuch as removal of the pectoral muscles does not greatly interfere with the usefulness of the arm and does facilitate the dissection of the axillary contents, it is perhaps better to remove at least a portion of the greater pectoral muscle along with the breast.

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* "The Expectancy of Life in Cases of Cancer of the Breast." Lancet, September 3d, 1900.

† "Further Statistics as to Results Obtained by Operations for Cancer of the Breast." Lancet, March 13th, 1899.

‡ St. Bartholomew's Hospital Reports, vol. xxiv., 1898.

In order to obtain better results, I think it is far more important to remove wider areas of skin and more of the adjacent fat, for we find that recurrences take place in the skin or fat a dozen times to one in the pectoral muscles.

The recent statistics of 100 cases of the Presbyterian Hospital of New York published in *The Medical News*, April 28th, 1900, by MacWilliams, still further support this view. His cases were operated on during the years 1889–99. In 48.9 per cent. of them the lymphatic glands were palpably enlarged. Yet of 75 cases which were examined microscopically after removal, 78.6 showed cancerous infection. The mortality of operation was 4 per cent.; and of 66 cases traced, 34 per cent. were well for a period of from 3 to 10 years. MacWilliams states that all the recurrences except 2 died within 2 years.

Here again we see the danger of generalizing from a single series of a small number of cases, especially as in 26 cases the after-histories were not traced. It is a significant fact that more than twice as many recurrences took place in the skin and scar than in any other locality. Of 34 recurrences 15 took place in scars and 6 in the lung; 3 in the opposite breast, and only 2 in the supraclavicular glands.

Halsted's brilliant "Results of Operation for Breast Cancer at the Johns Hopkins Hospital from June, 1889, to April, 1898,"* are of great interest and value. In all 133 cases were operated upon, 76 of these more than 3 years ago. There have been 13 (9 per cent.) local and 22 (16 per cent.) regionary recurrences. Of the 76 cases operated upon 3 or more years ago, 31 (41 per cent.) are living without local recurrence or signs of metastases; 10 died more than 3 years after operation, and 1 as late as 5.5 years after. Of these 10, 1 had a local recurrence. Forty cases, therefore (52 per cent.), lived more than 3 years without signs of local or regionary recurrences. Some of the 10 cases which died may have had, at 3 years, signs of metastases. Thirty-five (46 per cent.) died within 3 years of the operation, and 7 of these were local recurrences.

Dr. J. Collins Warren, in his valuable paper on "Curability of Cancer of the Breast," gives results of 72 cases operated upon during the past 15 years. Of these 38 died of recurrence of the disease, 26 are alive and well, 2 died of other diseases, and the remainder were not traced. Out of 50 cases in which recurrence was noted, in 34 the disease returned locally, either in the skin or subcutaneous fat, showing, as I have pointed out in most of the other statistics, that the present methods of operation fail to remove a sufficiently wide area of skin. In only 1 case did the recurrence take place in the supraclavicular region. Seventeen cases have remained well beyond 3 years, giving a percentage of 30.9 per cent. During the period of 1883–95, 22 cases were operated upon by more elaborate methods than the preceding cases; of these 36.3 per cent. passed the 3-year limit without recurrence; in all of the cases, however, the axillary glands were carefully removed. Warren states, with truth I believe, that the present experience with the new operations hardly justifies one as yet in deciding upon the limits of the curable cases. Until these limits are more strictly defined, it is probable that many incurable cases will be subjected to operation. He adds that it is his hope that wider experience will spare many a patient the ordeal of a useless operation.

With regard to glandular involvement, the glands were felt in the axilla in 54 cases; in 5 cases supraclavicular glands were noted; 3 of these died: 1 was alive, at time of writing, and 1 was not traced.

Warren's statistics emphasize some very important facts as to the duration of the tumor prior to the operative interference; the average period in 68 cases was 10.1 months. In 16 cures the average was 11.6 months, while in 38 failures it was 9.4 months. At first it seemed somewhat strange that the successful cases were operated upon later than the failures. Warren's explanation is probably correct, that the longer time during which the tumor had existed in the successful cases prior to operation simply shows the milder type of the disease. A person with a rapidly growing and consequently more malignant type of tumor is far more likely to be disturbed and to seek early surgical or medical advice than one with a more slowly and hence less malignant disease.

CANCER OF THE LIP.—Sarcoma of the lip is exceedingly rare, so rare that it is seldom mentioned by writers on cancer. I have personally observed one case of small, round-celled sarcoma of the lower lip in a little girl aged five years. The disease was twice removed, but recurred rapidly after each operation. It disappeared under the injections of the mixed toxins of erysipelas and bacillus prodigiosus, and is now well more than three years after operation. Cancer of the lower lip is almost always of the type of squamous-celled carcinoma, and rarely occurs in subjects under the age of forty years. The usual history is that of a slight irritation near the junction of the mucous membrane and the skin, resembling a small wart, which is irritated by the patient's picking and rubbing it. It frequently heals over, but in a short time the scab comes off and a small ulcer or fissure remains. It may continue for years with very slight increase in size. The duration of the disease is very variable, ranging between a few months and fifteen to twenty years. Death almost always occurs by exhaustion and seldom from metastases. The submental, submaxillary, and, finally, the cervical glands are likely to become involved in the order mentioned. The glandular involvement may occur early in the disease or it may be delayed for a long period. Simple enlargement of the glands does not always mean that infection has occurred. Butlin cites a case of a patient who died within a few months from the first appearance of the cancer, with extensive ulceration of the lip and secondary infection of a large number of glands. I have personally observed a similar case in a negro, in whom the disease ran such a rapid course that it strikingly resembled an acute infectious process. Within six weeks from the time the tumor was first noticed, the entire lower lip, floor of the mouth, and portion of the jaw, together with nearly all the glands in the neck, were infected, the latter being enormously enlarged. The patient died within three months from the inception of the disease, without metastases. In those cases in which the progress of the disease is very rapid, there is another point of similarity between cancer and acute infection, namely, a marked rise in pulse and temperature.

Method of Operation.—The only method that needs to be seriously considered is free removal with the knife or scissors, of a V-shaped portion of the lip containing the tumor and a wide margin of healthy tissue, from one-half to three-fourths of an inch beyond the border of the disease. In cases requiring removal of a large portion of the lip, the method of Malgaigne, or some one of the numerous modifications of the method, should be employed. The glands should always be removed when enlarged, and I believe that it is better to remove the submental and submaxillary glands as a routine measure in all cases, except in those in which the disease is of very short duration. The deformity caused by the removal of cancer of the lip is very slight when the tumor is small, and when it is large, almost the whole lower lip may be removed without causing great deformity, so long as the plastic operation is carefully and skilfully done.

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* Transactions Am. Surg. Assn., 1898.

Results of Operation.—The mortality of operation at the present time is very slight. In 896 cases collected by Wörner* there were 62 deaths, or a mortality of 7 per cent. Fricke's more recent statistics of the Göttingen Clinic, covering the years between 1874 and 1896, show 8 deaths in 114 cases, or the same mortality as that reported by Wörner. Five out of the 8 cases collected by Fricke, however, were complicated by removal of a portion of the lower jaw. The question of the necessity of removal of the glands in all cases Fricke's paper leaves still in doubt. In 8 of the successful cases they were not removed, although they were decidedly enlarged; yet the patients lived from 3 to 18 years after operation. Butlin states that at present he does not believe that routine operation for removal of the glands in every case of cancer of the lower lip is indicated. In Fricke's list they were removed in 24 out of 33 unsuccessful cases. This, however, does not prove that the patients would have done any better, had they not been removed. It seems wise to remove them in all cases, inasmuch as this procedure is not likely materially to increase the mortality, if at all. In Fricke's series the lower jaw was resected in 10 cases with 5 deaths; and only 1 of these cases was cured by the operation. Curiously enough, this case of cure was one in which the prognosis was exceedingly bad from the start. A second operation was done for extensive recurrence 4.5 months after the first, and yet the patient was well 11 years after.

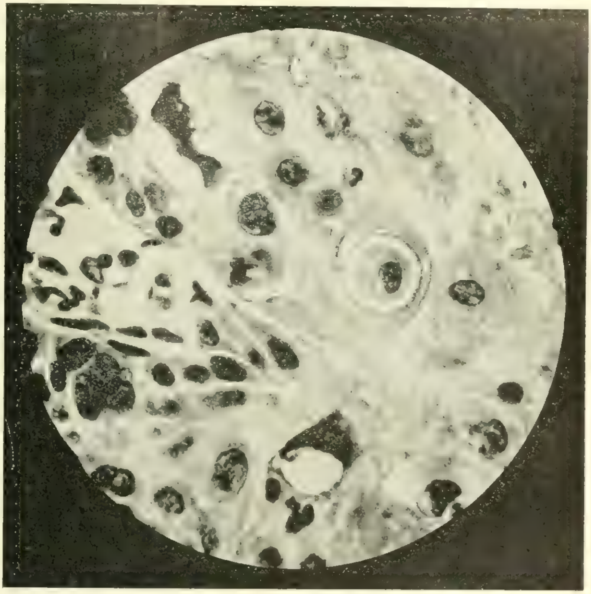
FIG. 1103. Epithelioma of Cervical Lymph Gland. Secondary to epithelioma of tonsil. (Buxton.)

Loos (*Beiträge z. klin. Chir.*, Bd. XXVII., May, 1900) gives an analysis of 565 cases of cancer of the lip treated at Bruns' Clinic, at Tübingen, 534 of which were of the lower lip and 31 of the upper lip. In three-fourths of the cases the glands were enlarged. The mortality of the operation during the period from 1843 to 1885, was 6.2%; from 1885 to 1898 it was 0.4%. The final results showed 51.6% successful in the earlier period and 66% in the later period. Of the cases operated upon between 1843 and 1884, 1 was well at the end of 45 years, 10 were well at the end of from 22 to 26 years, and 14 were well at the end of from 15 to 19 years.

The final results of operation for cancer of the lip are perhaps equal, or superior, to those in any other locality. The statistics of the cases at the Göttingen Clinic, 114 in number, mostly operated upon by König, show that 53 per cent. remained well more than 3 years after operation. Four hundred and twenty-four cases of cancer of the lower lip, collected by Butlin prior to the statistics of Fricke, show 38 per cent. of cures. After the disease has once recurred, there is very little hope of saving the patient by further operation. In only 3 out of 52 cases reported by Fricke as having passed the 3-year limit had there been a second operation performed. If the jaw is already involved, the prognosis is exceedingly bad. Butlin states that such operations are followed by a high rate of mortality, and are very rarely permanently successful.

CANCER OF THE TONGUE.—Cancer of the tongue, though less frequent than cancer in many other localities, is perhaps the most distressing of all to the patient. The disease usually begins along the free border, either at the extremity of the tongue or on one side. Not infrequently there is a history of irritation from a carious tooth. In the early stages the diagnosis may be difficult. The conditions most likely to simulate cancer of the tongue are: tuberculous, syphilitic, or chronic inflammatory affections. Tuberculosis may so closely resemble cancer that a careful microscopical examination may be necessary to differentiate it. Tuberculosis of the tongue, however, is so rare that it will seldom cause difficulty in diagnosis. I have, however, operated upon one case in which the clinical appearances pointed very strongly to epithelioma, and, in addition, a portion of the tumor removed for examination was pronounced epithelioma by the pathologist of a large hospital. When the anterior portion of the tongue was removed, further and more careful examination showed that the disease was not epithelioma, but tuberculosis. Syphilitic lesions may closely simulate cancer, but in most cases we are able to find other evidence of specific disease, even if the history is denied.

The treatment consists in removal of the whole or part of the tongue as soon as the diagnosis is made. The choice of operation depends somewhat upon the extent of the involvement. If the muscular portion of the tongue is involved, especially of the posterior region, better results may be obtained by the method known as Kocher's operation. Whitehead's operation, or a slight modification of the same, including preliminary ligature of the lingual arteries and removal of the sublingual and submaxillary glands, will, I believe, prove the best method in the great majority of cases. Its advantages over Kocher's method are very great. The mortality is much lower, and the wounds are more likely to heal primarily. Kocher's method is open to the serious objection that, in dragging the tongue out through the floor of the mouth, it is impossible to prevent the tumor, usually in an ulcerated condition, from coming in contact with the freshly cut healthy tissues, thereby running the risk of new infection. Curtis' suggestion of removing that part of the tongue containing the tumor through the mouth and completing the operation by Kocher's method, is objectionable in that it unnecessarily complicates the operation. The results of Whitehead's method are equal, or superior, to those obtained by Kocher's method. The question of how much of the tongue it is necessary to remove is a very important one. Some surgeons advocate removal of the entire tongue, even if the disease is comparatively limited in extent. Butlin does not believe that the entire tongue should be removed in every case. He states that the aim of the operator should be to remove the disease and about three-fourths of an inch of healthy tissue. If the disease is on the border of the tongue, the best practice is to remove that half of the tongue to an inch behind the disease. When it is near the tip or fore part of the dorsum, the fore part of the tongue should be removed. Butlin does not advocate the preliminary ligature of the lingual arteries as a routine measure. In my own cases I have usually tied the linguals prior to removal of the tongue, and this does not really complicate the operation, inasmuch as the glands of the neck may be removed through the same incisions which expose the arteries. Butlin's latest method of dividing the operation into two stages has much to recommend it. Thorough dissection of the anterior triangle of the neck and removal of all the glands is in itself a considerable operation, and if to this is added the removal of the tongue, the mortality is likely to be higher than if the operation were divided into two stages. Butlin now removes the disease of the tongue first, and about three weeks later the anterior triangle is opened and the glands are removed.

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* Beitr. z. klin. Chir., II., 129, 1886.

Results of Operation.—The latest statistics, comprising 33 cases of Krönlein, 59 of Kocher, 139 of Whitehead, and 102 of Butlin, giving a total of 333 cases, show 42 deaths from operation. Whitehead's personal cases (139 in number) show 20 deaths, or a ratio of 14.3 per cent. In 23 deaths in which the cause was stated, pneumonia and sepsis account for 12. As regards final results, 199 of the 333 mentioned were traced. Of these, 40, or 20 per cent., were well and free from disease or had died from other causes than cancer, upward of 3 years after operation. Butlin's personal statistics show 10 deaths in 102 cases. The remaining 92, with 7 exceptions, were traced to final results. Of these, 20 were well from 3 to 12 years after operation. In 18 cases there was local recurrence, in 28 glandular alone.

Operative treatment is contraindicated if the disease extends far back, or if the glands of the neck are markedly enlarged and fixed, or if the jaw is involved.

CANCER OF THE FACE.—The face is one of the most common sites for cancer, the probable reason being that it is more exposed to various sources of irritation. The most common type of cancer found in the face is rodent ulcer. There is very little difference in the two sexes as regards the frequency of cancer in this locality. Of 200 cases collected by Butlin, 110 occurred in the male, 90 in the female. The mortality of operation is comparatively high. Butlin's statistics of 206 cases of cancer of the face, mostly rodent ulcer, show 21 deaths, of which 9 were due to erysipelas. The more recent statistics show a lower mortality. In 100 cases treated at the St. Bartholomew's Hospital, in 1889–1898, there was only one death.

As regards permanent cure, the prognosis is good if the disease is attacked early. Krönlein's cases show 36 per cent. well beyond 3 years. But in this particulas locality we must bear in mind the fact that late recurrences (namely, at periods considerably beyond 3 years) are by no means infrequent. Glandular involvement is very rare in rodent ulcer of the face, and the disease destroys life by local extension and gradual exhaustion. This form of cancer is perhaps the most distressing and painful of any with which we have to deal; and while it, in most instances, could be cured if attacked very early, when once it has gained a firm foothold it is exceedingly difficult to eradicate. This is the form of cancer in which caustics of various kinds have been most frequently employed. While it is unquestionable that rodent ulcer in the early stages may be cured by caustics, we believe that in the great majority of cases better results will be obtained by the knife. Besides, they are obtained in a shorter time and with less pain and discomfort to the patient. One of the best caustics to be employed for cancer in this locality is the liquid butter, or terchloride, of antimony, applied by means of a glass rod. As regards the value of caustics, Butlin states "there is not the slightest reason why even extensive rodent ulcer of the face should not be treated by caustics with as thorough success as if the knife had been employed." He admits, however, that, as usually employed, they destroy only the surface of the disease, leaving the base behind and, hence, doing more harm than good. To be of any value, they must be used freely and vigorously. Butlin believes that Vienna paste is the best form of caustic. It is applied in a thick layer over the area to be destroyed, including half an inch of apparently healthy integument all around the ulcer.

CANCER OF THE STOMACH.—Malignant disease of the stomach is practically always carcinoma. Sarcoma, though occasionally found, is extremely rare. It may be either the columnar-celled or the squamous-celled variety, the former being by far the most common.

Diagnosis.—The diagnosis in the early stage is difficult, and inasmuch as it is important that it should be made at a very early moment if treatment is to be of much avail, the tendency at present is more and more in the direction of an early exploratory operation. With careful aseptic precautions this exploration is not likely to be attended with appreciable risks.

Hemmeter advises operation: (1) in the presence of dilatation; (2) in the presence of cachexia; (3) in the absence of hydrochloric acid; (4) in cases of excess of lactic acid; (5) in the presence of the Oppler bacillus.

Operative treatment consists in gastrectomy, complete or partial; pylorectomy or gastro-enterostomy. Space will not permit a description of the various operative methods. (See *Stomach, Surgery of the.*)

Results of Treatment.—Up to the present time 7 cases of complete gastrectomy have been reported, with 3 deaths. Seven other cases of nearly complete gastrectomy have been operated upon, with 2 deaths. The mortality of pylorectomy, as estimated by Haberkant* from a study of 257 cases, operated upon between the years 1881 and 1887, is 64.4 per cent. Between 1887 and 1894 it is 42.8 per cent. Goffe † found the mortality to be 76.5 per cent. in English and American cases during 1882 and 1890; 28.6 per cent. between 1890 and 1898. Individual statistics show much better results. For example, Krönlein operated upon 24 cases with 5 deaths, and only 2 deaths occurred in his last 20 cases. As to the duration of life after pylorectomy, Haberkant found that in 51 cases traced, 21 were alive from 1 to 8 years after operation. Nine of these were well for over 3 years. The improvement of later results is attributable to earlier exploratory operations and more extensive excision of the stomach. The high mortality of earlier days was largely due to postponing the operation until the strength of the patient was insufficient to stand the shock.

CANCER OF THE INTESTINE.—Cancer may occur in any portion of the intestines from the stomach to the rectum. The relative frequency of its occurrence in the different portions of the intestines is well shown by the statistics of de Bovis:

Cancer of the rectum, 49.2%; colon, 20.4%; sigmoid, 11.9%; small intestine, 6.3%. Sarcoma may occur, but is extremely rare. Madelung has collected 14 cases of sarcoma of the small intestine. Carcinoma occurs most frequently between the ages of 40 and 65 years. R. de Bovis (*Revue de Chirurgie*, 1900, Nos. 6 to 12) has given us the most extensive and valuable contribution to our knowledge of cancer of the large intestine yet published. He collected 426 cases of cancer of the large intestine (exclusive of the rectum). Of these, 53.9 per cent. were among males, and 46 per cent. among females. The diagnosis is seldom made until the growth has advanced sufficiently to cause stenosis in the bowel. Furnevall states that crises of paroxysms of colic, or periods of prolonged constipation and diarrhœa, with early weakness and progressive wasting in spite of medical treatment, are important symptoms. In several instances I have noticed that localized distention, due to the accumulation of gas in front of the stricture, is an important sign. This is sometimes observed by the patient himself, and regarded as a lump or tumor. Sometimes by manipulation it disappears with a slight gurgling sound.

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* Arch. f. klin. Chir., 1896, Bd. 51, p. 484.

† "Lectures on the Surgery of Diseases of the Stomach," by Barker.

Operative Treatment consists in resection of the bowel, making anastomosis, short-circuiting the constriction, or, if the disease is situated lower down toward the rectum, making colostomy. If the disease is in the small intestine, the Murphy button can be employed with advantage. Czerny states that he has given up its use in the colon for the reason that the lumen will become blocked with semi-hardened fæces, and the patient will die of obstruction. R. de Bovis (*loc. cit.*) states that in his series of 426 cases of cancer of large intestine, Murphy's button was employed 14 times with 4 deaths. Of these deaths 3 were attributed to the button. In 1 patient upon whom I personally operated, and in whom I did a double resection of the sigmoid and seven inches of an adherent loop of small intestine which had become involved by contiguity, I employed two Murphy buttons, one for uniting the ends of the small intestine, and the other, a large, oblong button, for making a lateral anastomosis between the closed portion of the ascending colon and the cæcal end of the small intestine. The patient made an uneventful recovery; both buttons passed on the ninth day. The patient remained well for 1 year and then had a slight recurrence in the parietal peritoneum. He is alive and in good general health at present, twenty-one months after the operation. The mortality of resection of the large intestine in 241 cases collected by Lardinnois was 34.8 per cent. Czerny's mortality for resection of the large intestine is 50 per cent.; Woelfler's, 54 per cent. in 114 cases. Wallace reports 12 cases of resection at the St. Thomas Hospital, London, between 1888 and 1897, with 7 deaths, or 58.3 per cent. Of 51 cases collected by Frank between the years 1884 and 1888, only 1 was known to have lived more than 3 years without recurrence. Woelfler, however, has collected 17 cases that were well from 4 to 16 years after operation.

R. de Bovis found the mortality in 101 cases of entero-anastomosis for cancer of the large intestine to be 38.6 per cent. The average duration of life after the operation of entero-anastomosis was 6.4 months, and the total average duration of life from the inception of the disease 21.2 months. Of 171 cases treated by resection the mortality was 31.5 per cent.—de Bovis believes that 38 per cent. is the actual present mortality. Up to 1889 it was 58 per cent. Fifty-one cases operated upon by 22 of the most distinguished continental surgeons since 1889 show 37.2 per cent. mortality. Of de Bovis' series of 171 enterectomies there were only 8 cures.

CANCER OF THE RECTUM.—Cancer of the rectum rarely occurs before the age of 35, and it is seen more frequently in men than in women, the proportion being about 6 to 5. It forms 4 per cent. of all cases of cancer. The symptoms during the early stages of the disease are ill defined, and usually consist more in a feeling of heaviness and discomfort than in one of actual pain. Stools are apt to be scanty and more frequent than usual. Constipation often alternates with diarrhœa. Later on, there is actual pain and occasionally some blood passes with the stools. The rectum should always be examined in suspicious cases. Carcinomatous ulceration shows the characteristic induration with hard, irregular margins, and if the disease is within reach of the finger, which is usually the case, the diagnosis is not often very difficult, except in the very early stage. In addition to digital examination, the speculum should be used in cases in which there is still doubt, and a portion of the suspicious area should be removed and examined microscopically.

Treatment.—The only treatment to be recommended is excision of the rectum in all cases in which it is possible to remove the disease. The choice of methods lies between the sacral or Kraske's operation, and the older perineal method. During recent years Kraske's operation has been adopted by most American as well as continental surgeons for all cases of cancer of the rectum, on the belief that its results were so much more promising as to outweigh the higher mortality. Even Watson Cheyne, one of the best representatives of sound and conservative English surgery, states that while the perineal operation is suitable in some cases, in the majority it is best to employ one or the other of the methods which give good access to the part from behind, such as Kraske's operation or some of its modifications. Comparing the results of the perineal with Kraske's method up to 1896, Cheyne states that the mortality of the perineal method seems to be about 8 per cent.; that of the sacral, 18 or 20 per cent. The results of operative treatment of cancer of the rectum at Küster's Clinic, Marburg, since 1885,* reported by Wendel, throw valuable light upon the comparative value of these different methods. The total number of cases observed was 126. Of 46 cases operated upon by the perineal method, 8 died directly or indirectly from the operation. Of the 38 remaining, 35 were traced. Six of them were well from 3 to 5 years; 3 from 7 to 11 years after operation. Of 46 cases operated upon by Kraske's method, 14, or 30.4 per cent., died of the operation; 26 of the remainder were traced to final results, and 5 were alive from 6 to 11 years after operation. Thus, the mortality of the sacral method was nearly double that of the perineal; and the final results as regards cures were inferior. As Wendel points out, these figures should not be taken as a true indication of the relative value of the methods, as in many of the cases operated upon by the Kraske method the disease was more advanced. The duration of wound healing is much longer in the sacral than in the perineal operation, the average duration being 64 days in the sacral. Wendel concludes that 9.4 per cent. of the cases in which radical operation was performed survived from 6 to 12 years without recurrence. Adding to these the cases that died of other diseases without recurrence, he estimates the number of final cures at 16.8 per cent. Kraske's personal results in 80 cases show a mortality of 18.7 per cent. and 6.2 per cent. of cures. Hochenegg operated upon 89 cases by the sacral method with a mortality of 9 per cent. and 12.49 per cent. of cures. Mikulicz's 57 cases operated upon by Kraske's method show a mortality of 24.56 per cent. and 6.69 per cent. of cures.

These statistics, combined with those of Kraske, show a mortality of 18.7 per cent. and 10 per cent. of cures. They certainly justify the conclusion of Wendel that there is no reason for ignoring the perineal method to the extent that it has generally been done. The plan adopted at Küster's Clinic might well be followed by others. It is, never to decide beforehand what method of operation is to be performed, but always to employ that method which best meets the conditions of the individual case. Whenever the cancer is within easy reach and well defined, the perineal method should be chosen. In cases in which the disease is located high up, or complicated by inflammatory infiltrations of the neighboring tissues, extension of the tumor to the adjacent parts, the sacral method should receive the preference. Wendel believes that in one-half of the cases reported it is possible, or even preferable, to operate after the perineal method.

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* Deutsche Zeitschr. f. Chir., January, 1899, Bd. l., Hefte 3, 4.

Heinrich Wolff, in his article on the "Radical Operation for Cancer of the Rectum," * refers to the apparently contradictory statements as regards results in the statistics of various authors, and says that the same are due to the different views taken by different writers with regard to the indication for operation before and during the interference.

Of 155 cases of cancer of the rectum (101 men, 57 women) admitted to the Clinic between 1888 and 1900 (excluding those of 1900), 125, or 80.6 per cent., were subjected to radical operation. On the other 30 cases no operation at all, or palliative operation, was performed. In 60, or 48 per cent., of the 125 cases of radical operation, amputation of the rectum, and in 65, or 52 per cent., resection of the rectum, was done. The ages of the patients ranged between 20 and 80; 7 between 20 and 30; 14 between 30 and 40; 126 between 40 and 70; 8 between 70 and 80. Of the 60 cases of amputation of the rectum, 9, or 14.7 per cent., died in consequence of the operation. Of the 51 patients on whom the operation was successfully performed, 39 were traced, and of these 12 are still living, 1 with a recurrence more than 3 years after operation. The remaining 11, or 28.2 per cent., of the number traced, are alive and free from recurrence from 3 to 11 years after operation. Of the other 27 who survived the operation, 17 died within the first 2 years; 7 within the third year after operation; 2 lived 3 years 9 months each, and one 5 years. The majority died of recurrence. In most of the cases of amputation of the rectum it was necessary to operate by the sacral method. In 17 instances no bone operation was done (Lisfranc, Kocher); in 21 instances the coccyx was extirpated, and in 8 instances the coccyx and part of the sacrum were resected. The peritoneum was opened in about one-half of the cases.

In the 65 cases of resection of the rectum the peritoneal cavity was opened as a rule, but immediately after the gut had been drawn down the peritoneal cavity was closed by suture. In 2 cases laparotomy was performed (1 death and 1 permanent result). In all of the remaining 63 cases the sacral method was used; 46 times an osteoplastic preliminary operation was done—*i.e.*, 8 times temporary resection of the coccyx; 38 times temporary resection of the sacro-coccyx. Of the 65 cases of resection, 31, or 47.7 per cent., died; of these, 20 in direct consequence of the operation, 11 of complications, such as pneumonia, general cachexia, embolism of lung, etc. Of the 34 who survived the operation, 28 were traced. Of these, 8 are still living, 1 with a recurrence 1 year and 6 months after operation. Of the remaining 7, 1 is well and free from recurrence 1 year and 5 months after operation; 1, 2 years after operation; 2, 3 years; 1, 3 years and 3 months; 1, 7 years and 9 months; and 1, 11 years after operation. Of the other 20, 10 died during the first year; 8 during the second and third years; and 2, 3 years and 9 months and 4 years and 6 months, respectively, after operation. All succumbed to recurrence except the last 2, who died of intercurrent disease. If we include the latter among the permanent cures and exclude the 2 cases that are free from recurrence less than 3 years after operation, we have 7 out of 26, or 26.9 per cent., of permanent cures. The total mortality of all the cases of radical operation (resection and amputation) is 40 out of 125, or 32 per cent. Counting only the deaths directly due to operation (27), we have a mortality of 21.6 per cent. Twenty of the deaths were due to collapse. Not 1 of the 60 cases of amputation, and only a very small number of the 65 cases of resection, died of infection, a circumstance which Wolff ascribes to the "fully open" treatment of the wound and extensive use of iodoform gauze. The total number of permanent cures obtained in the entire series of 125 is 27.5 per cent.

As regards continence, there were 9 cases of absolute continence. In 7 instances the continence was relative. In 1 case it was moderate, and in 1 there was absolute incontinence. On the whole, the patients were able to insure an almost complete continence by exercising a little care in regulating their stool.

Cancer of the Parotid Gland.—Cancer of the parotid gland may be of different types; mixed-celled sarcoma is, however, the most common. The malignancy of these tumors varies within wide limits. Formerly nearly all the growths were regarded by pathologists as carcinoma. Later observers were inclined to class them as sarcoma, while at present the tendency is to group many of them as endothelioma. The classification is extremely complex and difficult. Butlin believes that the only course left open in dealing with the subject from a clinical and operative standpoint, is to consider all malignant growths of the parotid under the common name of "cancer." This certainly seems the most rational course. Some of these tumors of the parotid run an extremely rapid course. I have personally observed one, a round- and spindle-celled sarcoma of the parotid of high vascularity, which developed in a man, aged forty, immediately after a blow from a horse's head. It grew very rapidly and was removed a few weeks later. Recurrence quickly following, a second and a third operation were performed without checking the progress of the disease, which proved fatal in about four months from the date of its origin. I have had under personal observation 12 cases of malignant disease of the parotid; all of these were classed by pathologists as sarcoma, mostly mixed-celled, although some were pure round- and some spindle-celled. Two of these cases that were recurrent and inoperable at the time of first observation, and hopeless, have been apparently cured by the mixed toxins of erysipelas and bacillus prodigiosus, 1 having remained well more than 4 years, and the other upward of 3 years after treatment.

According to Butlin, the prognosis after operative treatment is extremely bad. Three out of 17 patients in his statistics died of operation, and it is not stated that any remained well long enough to be considered cured. Butlin states, with regard to cures, that up to the present time there are very few instances of cures by operation of undoubted malignant disease of the parotid. One probable reason for this is, that up to the present time surgeons have been too anxious to save the facial nerve and, hence, the operations have not been sufficiently extensive to eradicate the disease. If there is to be a reasonable prospect of curing the patient by operation in the future, the facial nerve will undoubtedly have to be sacrificed.

Cancer of the Penis.—Cancer of the penis almost always takes the form of carcinoma, sarcoma being exceedingly rare, only 10 cases having been collected from the literature. Epithelioma is the type of carcinoma most frequently found, and it usually begins at the junction of the prepuce with the gland. The disease seldom occurs before the age of 50 years, and is most frequently seen between 50 and 70.

In making a differential diagnosis, the condition most likely to simulate cancer of the penis is a specific ulcer. The absence of a history of infection or other signs of syphilis will enable us to make the diagnosis. If the lesion is very small and there is doubt as to its character, a small portion may be safely removed under cocaine and submitted to microscopical examination. Secondary infection of the glands in the groin usually occurs, though not, as a rule, until the disease has existed for a considerable time. The average duration of a cancer of the penis without operative treatment is about 3 years.

As to methods of operation, partial or complete amputation of the penis is usually indicated. Although the cautery has been advised by some, the knife is to be preferred. The inguinal glands should in all cases be removed, whether they can be felt or not. If the operation is performed under the best aseptic conditions, the mortality is comparatively low. The risks of death from hemorrhage are very slight. The vessels should be tied as they are cut, and the oozing from the corpus cavernosum may be checked by pressure from iodoform gauze. The mortality as estimated by Butlin is 6 per cent. in the simple operation, but considerably greater in the cases in which complete extirpation of the penis, together with the inguinal glands, has been performed.

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* Arch. f. klin. Chir., lxii., i.

As regards the final cures, Butlin reports 65 cases that were traced for 3 years, in addition to 16 others that were alive and free from recurrence for periods ranging from a few months to from 2 to 3 years. Of the 65 patients 23 were well beyond 3 years, giving a proportion of successful cases of upward of 35 per cent. Butlin states that in almost all the successful cases the operation consisted in simple amputation of the penis and not extirpation, the disease having been at or near the extremity. The number of cases in which the inguinal glands were removed is not known.

H. Küttner, in his article entitled "Carcinoma of the Penis and Its Dissemination through the Lymph Passages,"[*] furnishes some very valuable data based on a series of 60 cases observed at the Tübingen (Bruns') Clinic. He states that while for the local extension of the disease the vascular system is of greatest importance, it is of little or no account as regards metastatic spread, internal metastases being of rare occurrence; in addition to 1 of his own cases reported, he has been able to find but 9 such cases in the literature. He has made some extensive anatomical studies, and gives his conclusions, which are very important.

As regards the prognosis of carcinoma of the penis, Küttner states that there is hardly a carcinoma which offers such favorable conditions for a permanent cure as this. This is partially due to the fact that in a large percentage of the cases the disease remains local for a long time and shows little tendency to invade the regionary lymphatic glands, or to form metastases even in cases in which the tumor has become very extensive locally. It may be mentioned here that in 73 per cent. of the permanent cures obtained at the Tübingen Clinic the glands were not removed, although the disease had existed from 1 to 4 years prior to operation. Of the 60 cases reported by Küttner 53 were operated upon, with 3 deaths, a mortality of 5.6 per cent. Excluding these, as also those that could not be traced, there remain 37 cases, 15, or 40.5 per cent., of which died of recurrence; while 22, or 59.4 per cent., were permanently cured, *i.e.*, they remained well and free from recurrence upward of 3 years. Of these, 9 died of other causes within 3 to 29 years after operation. Thus there are 13 still living free from recurrence, the youngest of them 3 years and 6 months after operation, all others having lived longer: 3 upward of 20 years after operation; 2, 10 years, and these were operated upon at the age of 70 and 71 years, respectively, showing that age need not deter us from operating.

As to the 15 cases that died of recurrence, details are missing regarding 3. Of the remaining 12, 11, or 91.7 per cent., had a recurrence in the glands. The rapidity with which recurrence followed operation is remarkable, in some instances within a few weeks.

The question as to the advisability of removing the inguinal glands, Küttner believes, is of paramount importance. It is his opinion that the glands should be extirpated in all cases in which the tumor is of a malignant character and has not already too far advanced. If the tumor is of slow growth, and the glands are not enlarged, he thinks that, in view of the favorable results obtained at the clinic in the cases in which the glands were not removed, amputation of the penis may be done without removal of the glands if the patient is disinclined to allow the latter or if a more extensive operation be contraindicated. In such cases as come under the surgeon's care at a very early stage of the disease, he even considers it advisable not to remove the glands on account of the difficulty of keeping wounds in the inguinal region perfectly aseptic, so that the danger from probable wound complications may be greater than that from the cancer. In all other cases he believes the glands should be removed on both sides, as a matter of principle. He does not approve of total emasculation according to Thiersch, a procedure so often recommended of late.

The frequency of carcinoma of the penis ranges, according to various statistics, between 1 and 3 per cent. of all other carcinomata. He found in 1,188 cases of carcinoma reported between 1885 and 1898, 27 cases, or 2.27 per cent., of carcinoma of the penis. Excluding cancer in women, the total number of cases of carcinoma in all localities was 577, with a percentage of 4.68 of carcinoma of the penis.

As regards the age at which the disease most frequently occurs, he found that out of a series of 562 cases, including his own, 4.3 per cent. had not exceeded the age of 30; 9.1 per cent. were between 31 and 40 years; 23.3 per cent. between 41 and 50; 30.1 between 51 and 60; 22 per cent. between 61 and 70; 10.3 per cent. between 71 and 80; and .9 per cent. between 81 and 90.

Five of the cases reported by Küttner gave a history of previous injury.

CANCER OF THE TESTIS.—Malignant disease of the testis may be either carcinoma or sarcoma, although sarcoma is by far the most frequent. Among 17 cases that have come under my personal observation, there has been only 1 case of carcinoma. Butlin states that malignant disease of the testis may occur in children, but seldom in children beyond 10 years of age, and rarely in adults under 30 years of age. My own experience, although the same as regards children, has not been in accord with Butlin's statement with reference to young adults, as more than one-half of my cases have been in young men between 20 and 30 years of age.

In regard to diagnosis, careful inquiry should be made as to a history of previous injury. In one-half of my own cases there was a distinct history of antecedent trauma. The physical characteristics of the tumor are in most cases sufficiently marked to make the diagnosis comparatively easy. A solid tumor, associated with more or less pain, gradually increasing in size, symmetrical in shape, especially if associated with a history of previous injury, would make one strongly suspect malignant tumor of the testis. The only disease likely to simulate it is a syphilitic orchitis or a teratoma. The slower development and previous history of syphilis would, in most cases, enable one to differentiate the conditions. The diagnosis of teratoma can be made only with the microscope. If the diagnosis is in doubt, exploratory operation should be promptly done.

Treatment.—The only treatment is castration and removal of the cord as well as cord vessels well within the internal ring. The incision which I have usually employed in these cases has been similar to that used in Bassini's operation for inguinal hernia, splitting up the aponeurosis well beyond the internal ring, which enables one to make a thorough removal of the cord. The inguinal glands, if involved—which is seldom the case in sarcoma—should be removed at the same time. Sarcoma of the testis is one of the most malignant forms of cancer with which we have to deal, and cures due to operation, even when undertaken in the early stages of the disease, are comparatively rare. Butlin has collected 118 cases with only 6 well more than 3 years after operation. The valuable statistics of Kober[*] show 106 cases with 9 well more than 3 years after operation. Of the 16 cases observed by myself, not a single one was cured either by operation or by toxin treatment. Recurrent sarcoma of the testis seldom attacks the inguinal glands, but almost always appears in the retroperitoneal glands. The usual course of these cases is speedy recovery from the operation, the patient feeling comparatively well for a number of months, in rare cases more than a year after operation. He then discovers a hard mass in the abdominal cavity, due to the development of a sarcomatous tumor in the retroperitoneal region. This increases sometimes to the size of a man's head, filling up a large portion of the cavity, and causes constipation from pressure. In some cases before death occurs, metastatic deposits have formed in the liver and lungs. The average duration of life is seldom more than 1 or 2 years after operation. The usual type of sarcoma in this region is the round-celled. In 1 of my own cases the tumor was melanotic.

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[*] Beitr. z. klin. Chir., vol. xxvi., No. 1, 1900.

[*] Am. Journ. of the Med. Sciences, 1899, v., p. 35.

CANCER OF THE VAGINA.—Both carcinoma and sarcoma occur in the vagina, although carcinoma is more common. In sarcoma the growth not infrequently resembles polypus, and it may reach considerable size before ulceration and hemorrhage occur. Carcinoma is more frequently found in the posterior than in the anterior wall of the vagina. It extends by infiltrating the neighboring tissues, and ulceration is found in the early stages.

Cures of malignant disease of the vagina are comparatively rare, and are obtained only by very early and extensive removal of the disease and the surrounding tissues. Butlin has collected 75 cases, of which 37 were sarcoma, 38 carcinoma. Seven of the patients were alive and well more than 3 years after operation; 5 of these had sarcoma, 2 carcinoma.

CANCER OF THE KIDNEY.—Malignant growths of the kidney are comparatively rare, being only five-tenths of 1 per cent. of all malignant neoplasms, according to Virchow. Kelynack, however, who has perhaps made the most thorough study of this subject, believes this estimate to be too small, and thinks 2 to 3 per cent. nearer the truth. Sarcoma is much more common than carcinoma, the reverse of the opinion held a few years ago. Many of the cases which in the various statistics were originally reported as cancers were undoubtedly sarcoma. Fifty per cent. of the cases of sarcoma of the kidney occur in children under the age of 10 years. Seventy-four out of 160 cases collected by Kelynack were in patients under 5 years of age. A tumor, situated in the space between the border of the rib and the crest of the ilium, is a most important physical sign in making the diagnosis. It varies greatly in size from a few ounces to 36 pounds. The position of the colon overlying the tumor is an important point in making the diagnosis. While the consistence of the tumor varies, fluctuation can usually be detected owing to cystic degeneration. Hæmaturia is also an important sign. In children the growth is usually very rapid, and often attains large size before it is noticed even by the mother. The conditions most likely to simulate it are omental and mesenteric tumors, cystic kidney, tuberculosis, hydronephrosis, and perinephritic abscess.

Treatment.—Until very recently the consensus of surgical opinion has been against operation, the results of operation having been so uniformly bad that little hope of cure was offered. American surgeons, one of whom was the first to perform nephrectomy for renal tumor, have been largely responsible for a change of opinion. At present the mortality of the operation is not far from 50 per cent. Of 150 cases collected by Czerny only 5 were beyond five years. Of 145 cases in children under 14 years, collected by G. Walker (Annals of Surgery, 1897, p. 529), only 4 survived beyond three years, and one of these has since died.

Careful examination of all the cases of malignant disease of the kidneys in which operation has been performed, and study of the final results, justify the conclusion, I think, that while the prognosis is still extremely bad, especially in children, operation should be advised in all cases in which there is reasonable probability of removing the entire tumor; and every portion of the fibrous capsule should be removed along with the tumor itself.

SARCOMA.

Sarcoma may occur at any age, though it is more frequent between the ages of 20 and 50 years. Of 136 cases observed by Roger Williams only 24 were under the age of 20 years. My own series of 316 cases shows a larger proportion in young persons; 62 were under the age of 20 years. I have observed 4 cases of sarcoma of the femur in persons under the age of 10 years.

Sex.—The male sex is more liable to sarcoma than the female. Of my 316 cases, 288 were male and 28 female.

Anatomical Situation.—A thorough knowledge of the parts of the body most prone to sarcoma will often be of aid in making a diagnosis. It is a remarkable fact that the disease very commonly attacks bony structures and shows a decided preference for certain bones, and especially the femur. Of 316 cases of sarcoma that I have personally observed, 84 originated in bones and 232 in the soft parts. Of the bones, the femur was most often the starting-point of the disease, as shown in the following summary:

LOCATION.	NO. OF CASES.	LOCATION.	NO. OF CASES.
Femur	13	Pubic bone	11
Tibia	5	Rib	1
Fibula	2	Sacrum	2
Ilium	11	Humerus	3
Vertebræ	3	Clavicle	2
Superior maxilla	13	Sternum	1
Inferior maxilla	8	Metacarpal bone	1
Mastoid	3	Phalanx	3
Scapula	2		

Of the soft parts the neck furnished the largest number of cases. In no less than 30 patients the disease began as a primary lympho-sarcoma of the neck. In 20 it began in the orbit, and in 20 in the thigh.

SYMPTOMATOLOGY OF SARCOMA.—Pain is rarely present at the beginning of the disease. A "lump" or swelling is the first thing that attracts the attention of the patient. Injury plays a much more important part in the development of sarcoma than in that of cancer. Of my 270 cases analyzed with reference to trauma, about one-third, or 31.8 per cent., gave a distinct history of antecedent local trauma. The injury need not be a severe one, a blow or contusion being the usual form of injury. In a considerable number of cases (31 that I have personally observed) the tumor developed within a few days after the receipt of the injury, so quickly that there could be no doubt of the etiological relationship between the tumor and the trauma. These cases may very properly be classified as examples of acute traumatic malignancy.

Traumatic sarcoma may occur both in the bones and in the soft parts. Of my first series of cases 18 occurred in the bones and 26 in the soft parts. All varieties of sarcoma were included: 29 round-celled, 5 spindle-celled, 5 melanotic, 3 mixed-celled, and 2 doubtful.

At my request Dr. C. J. Kane, late house surgeon to the General Memorial Hospital, has recently made an analysis of the last 100 cases of sarcoma observed at the hospital during the past three years with reference to antecedent injury. He found that in 63 per cent. local injury of some form was noted at varying intervals before the development of the tumor, and that in 27 other cases there was a history of chronic irritation, leaving but 10 cases in which there had been neither trauma nor irritation. Of 270 personal cases analyzed with reference to trauma I found that 86, or 31.9 per cent., gave a history of distinct injury prior to the discovery of the tumor. In 31, or 11.5 per cent., the tumor developed almost immediately after the injury. The only reason for separating these so-called acute cases or examples of acute traumatic malignancy is that in these cases the connection between the injury and the tumor is so close and definite that it cannot be easily explained away. If we can establish an etiological relationship between the trauma and the development of sarcoma in this group of acute cases, the same relationship will probably be found to obtain in the cases of slower development. Various theories have been offered to explain the relation between trauma and cancer. The opinion that has received the most support has been the so-called "constitutional diathesis." The person possessing this diathesis is supposed to be in danger of developing a tumor after an injury, while another not possessing it will be safe. My own views already expressed (*Annals of Surgery*, February, 1898) are that the relationship between injury and the development of sarcoma or carcinoma can be most rationally explained on the theory that such tumors are of infectious or micro-parasitic origin. Granting for the moment this to be the true origin of malignant tumors, their development following an injury would be in perfect accord with tuberculous lesions of the bone that not infrequently develop from local trauma. We are also familiar with osteomyelitis and periostitis following local trauma without any lesion of the skin or known source of infection. Any explanation that would apply to these lesions would apply to sarcoma. The most probable explanation would appear to be that the infectious agent of the malignant tumor exists somewhere latent in certain individuals, and is harmless until some local injury, by diminishing the vitality of the tissues, lowers their resisting power, and thus furnishes a favorable nidus for the development of the tumor germs.

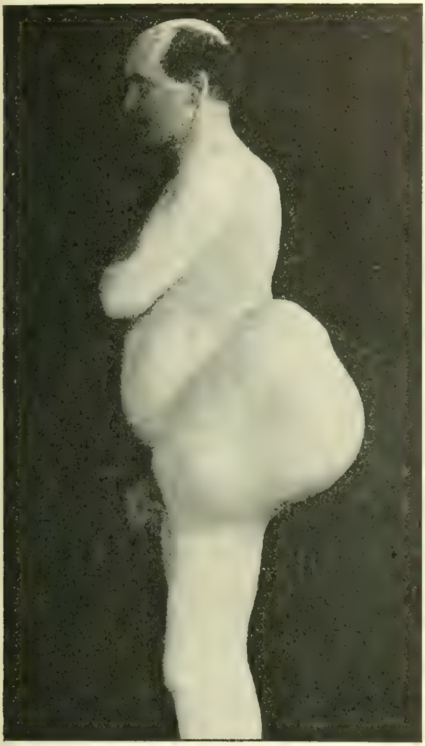

FIG. 1104.—Chondro-Sarcoma of the Ilium.

Character of Swelling.—This varies with the type of sarcoma. In the round-celled variety the consistence may be so soft as to resemble an abscess, and in certain cases it may be extremely difficult to differentiate a sarcoma from a deeply seated abscess, especially a "cold" abscess, originating from caries of bone. A sarcoma of high vascularity may have sufficient pulsation to simulate an aneurism. Pain is of less importance than is generally supposed. Sarcoma, like carcinoma, is seldom painful at the first, except in certain cases in which, from its anatomical situation, there is pressure upon important nerves. The most painful sarcomata that I have observed have originated in the vertebræ. I have observed four cases, and in all the pain has been very severe.

DIAGNOSIS.—The conditions most likely to be mistaken for sarcoma are tuberculous, syphilitic, and inflammatory swellings. A careful history, together with the physical signs, will in most cases enable one to make a correct diagnosis. Sarcoma usually develops more quickly than a tuberculous tumor. Pain is more frequent in sarcoma. Local heat is also usually present in sarcoma and absent in tuberculous swellings, and the superficial veins are more prominent in sarcoma.

Inflammatory swellings may even more closely simulate sarcoma. The more rapid development, greater pain and tenderness, together with more or less increase in pulse rate and temperature, will in most cases establish the diagnosis. We must remember, however, that in rapidly growing sarcomas we may also have an increase in pulse rate, and also a decided rise in temperature. Marked tenderness is, however, rare in sarcoma or carcinoma.

SARCOMA OF BONES.—Sarcoma may develop in any bone, but occurs most frequently in the long bones, especially the femur. It may be of either central or periosteal origin. Of Gross' collection of 165 cases of sarcoma of the long bones, 67 occurred in the femur, 46 in the tibia, 21 in the humerus, 13 in the fibula, 7 in the ulna, 6 in the radius. Of 24 personal observations of sarcoma of long bones 13 were in the femur, 5 in the tibia, 3 in the humerus, 2 in the fibula, and 1 in the radius. The periosteal tumors are of a much higher degree of malignancy than are those of central origin. The periosteal sarcomas usually start in the shaft or at some distance from the joint, while the central sarcomas begin near the ends. Reinhardt, who collected 54 cases of sarcoma of the long bones treated at the Göttingen Clinic between 1880 and

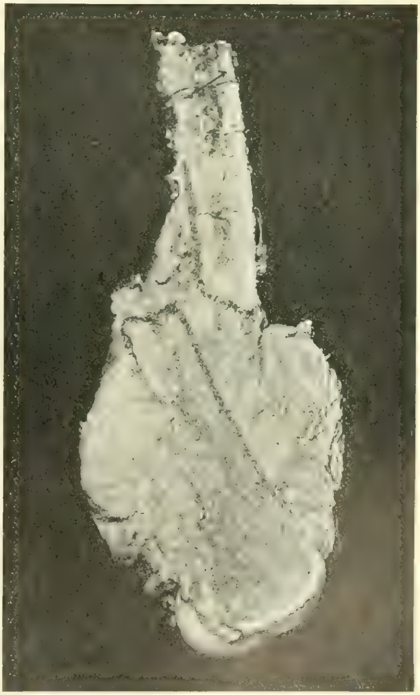

FIG. 1105.—Acute Traumatic Sarcoma of Femur in a Case of Recent Fracture, Caused by the Kick of a Horse.

1895, found 18 of the femur and 19 of the tibia. Metastasis occurred in 33 per cent. of the cases. The duration of the disease was from three months to nine years. The difference in malignancy between the round-celled and spindle-celled varieties was not apparent. Of 15 cases of spindle-celled sarcoma 2 were well over three years after the operation. Of 10 cases of the round-celled variety 3 were well over three years after the operation, and of the 54 cases, 7 (= 18 per cent.) were well after the lapse of the same period of time.

Periosteal sarcoma of the femur is probably the most malignant tumor that exists. Of 68 cases collected by Butlin, treated by the most extensive operations—either by amputation at the hip-joint or by very high amputation—only 1 was known to have been cured.

The prognosis of sarcoma in the long bones in general is better than in the femur alone. Gross found that of 90 cases traced for a considerable period after operation, 26.6 per cent. were well after a period of more than 3 years. His statistics also show that the giant-celled sarcomata are much less malignant than the other variety, two-thirds of the cases being of this type.

The only treatment to be recommended for sarcoma of the femur is amputation at the hip-joint. The mortality of the operation has been remarkably diminished by the introduction of more modern methods of controlling the hemorrhage and of keeping the wound aseptic. Wyeth's method of steel pins, I believe to be by far the best. I have used it in 6 cases of amputation of the hip for sarcoma—4 cases of sarcoma of the femur, and 2 cases of sarcoma of soft parts—without a single death. Butlin's statistics of 47 cases show a mortality of 25 per cent. Wyeth's recent statistics of 250 cases operated upon by this method show a mortality of only 22 per cent.; and, including cases of tumor only, the mortality was but 13 per cent.

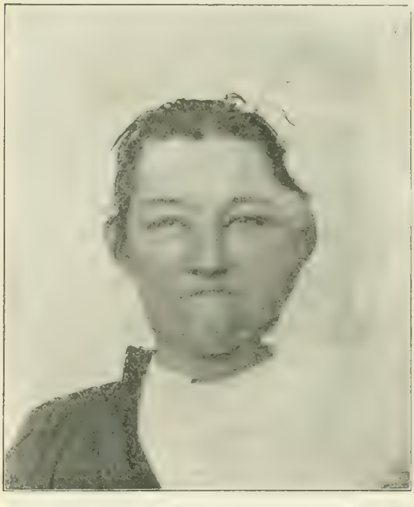

FIG. 1106. -Recurrence of Sarcoma of Lower Jaw, Ten Years After Resection of One-Half of Lower Jaw.

Even if the patient is not cured, the disease returns in the lungs or abdomen, and death is less painful and far less distressing than if amputation had not been performed.

Of 52 cases of sarcoma of the tibia and fibula collected by Butlin, 9 remained well for more than 3 years.

In cases of giant-celled sarcoma of the bones the question is not entirely settled as to the necessity of amputation. Butlin believes that in certain cases these tumors may be successfully treated by scooping out, and in others resection may be sufficient. He states, however, that for the large majority of central tumors (of the tibia or fibula) amputation through the lower part of the thigh or at the knee must be performed. Personally I do not believe it good surgery to scoop out or even resect a long bone for sarcoma. The mere operation of scooping out I believe materially increases the risk of generalizing the disease by getting the infected cells into the circulation. Amputation should be performed above the bone involved.

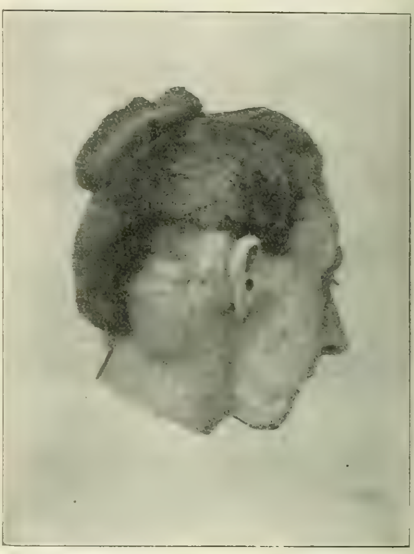

FIG. 1107.—Recurrent Sarcoma of Lower Jaw Five Years After Resection of One-Half of Inferior Maxilla.

Sarcoma of the humerus is rather rare. Butlin's statistics show 32 cases with 2 deaths due to operation, and with but 2 cases well long enough to be called cured.

Sarcoma of the radius and ulna is so rare that it need not be further mentioned.

Poinsot has collected 25 cases of sarcoma of the scapula with 2 deaths from operation, but with only 1 cure.

Doll (*Archiv f. klin. Chir.*, Bd. xxxviii., p. 131) collected 32 cases in which the scapula alone was removed for sarcoma, with a mortality of 25 per cent., and with no known cures.

SARCOMA OF THE UPPER AND LOWER JAW.—The jaw, both upper and lower, furnishes a frequent starting-point for sarcoma. It occurs usually in patients over 40 years of age. Martens collected 62 cases of sarcoma of the upper jaw operated upon at the Göttingen Clinic, and of these 50 were over 40 years of age and but 12 under 40 years. The disease usually begins in the alveolar process or in the region of the antrum. The first symptom is usually an irritation at the root of a tooth or a looseness of a tooth. The course of the disease is usually rapid, and often so rapid that the trouble is mistaken for an inflammatory condition. The mortality of resection of the upper jaw for sarcoma is about 30 per cent. Resection of the lower jaw for malignant disease gives a mortality of about 14 per cent. Butlin has collected 104 cases of resection of lower jaw for sarcoma with 8 deaths. Only 4 cases passed the 3 year limit. The accompanying photographs (Figs. 1106 and 1107) illustrate well the prolongation of life by operation, though final cure was not obtained. In 1 case the disease recurred behind the ear 5 years after operation, and in the other 10 years after operation. The recurrence took place in the tissues in a region formerly occupied by the angle of the jaw.

Sarcoma of the Lymphatic Glands (Lympho-Sarcoma, Hodgkin's Disease).—Sarcoma very frequently originates in lymphatic glands, especially in the glands of the neck. Of my 316 cases of sarcoma no less than 30 began in the lymph glands of the neck. The prognosis is almost absolutely bad. The type is usually small, round-celled, and operation, though performed early, rarely checks the progress of the disease. Butlin states that he "cannot discover a single instance in which a thoroughly successful removal has been accomplished." The accompanying photograph is a good illustration of a well-advanced lympho-sarcoma of the neck in a colored man. I operated in May, 1900, and apparently removed all of the enlarged glands, though some extended down under the clavicle to the pleura. I anticipated a speedy recurrence, but thus far, seven months after the operation, there has been no return. There is at present no well-recognized distinction in the use of the terms Hodgkin's disease, lympho-sarcoma, and malignant lymphoma, though all are used in describing sarcomatous disease of the lymphatic glands. In England there is a tendency to restrict the term lympho-sarcoma to the more rapid cases, particularly when associated with metastases, and to apply the term Hodgkin's disease to cases in which the glands alone are involved, and especially to cases in which the glands in different localities are affected. The illustration here given shows the latter type, the glands in neck, axilla, and groin being extensively involved.

Sarcoma of the Breast.—Sarcoma of the breast is one of the rarer forms of tumor found in this locality. It is rarer than either adenoma or fibro-adenoma. Of 100 cases of breast tumors collected by Bryant, only 4 were sarcoma. The majority of cases occur between the ages of 30 and 40. Of my own cases, 8 in number, all were over 30 years of age; 4 between 30 and 35; 4 over 35. Of 12 cases collected at the St. George's Hospital by Shield, 4 were between 30 and 40, 6 between 40 and 50, and 2 over 50 years of age.

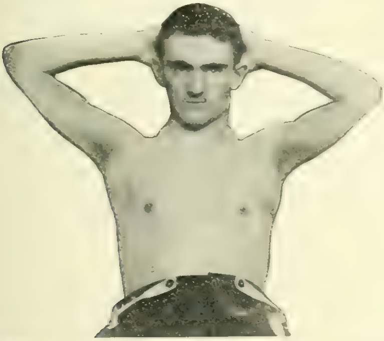

Fig. 1108.—Lympho-Sarcoma of the Neck and Axillæ. (Malignant lymphadenoma.)

As regards the comparative frequency of the various types of sarcoma, of 17 cases examined at the Royal College of Surgeons, 7 were spindle-celled, 4 mixed-celled, and 6 myxo-sarcoma. Ulceration and fungoid granulations will frequently occur in rapidly growing sarcoma of the breast of high vascularity, and may produce severe and even fatal hemorrhages.

An important point in differentiating sarcoma from fibro-adenoma is the age of the patient, the latter tumors being seldom found after the age of 30. History of previous injury, which is found in nearly one-half of the cases of sarcoma, furnishes an additional aid in diagnosis.

Treatment and *Prognosis*.—The technique of the operation does not differ materially from that for carcinoma. While recurrence in the axillary glands is not common, it is occasionally observed, and the glands should in all cases be removed together with the breast. The tendency to recur locally is very great. While the disease, especially the round-celled type, usually runs a rapid course, occasionally the patient may live for many years in spite of repeated recurrences. One of my own cases, an angiosarcoma of the breast in a woman 59 years of age, was operated on the first time in 1881. She remained free from recurrence 7 years, and then the tumor returned locally and grew for 2 years, when a second operation was performed. Two years later the disease returned a second time and continued to increase in size until the time of my first observation, January 20th, 1895. The tumor then was very large and entirely inoperable. Under 8 months' treatment with the mixed toxins, it decreased so much in size as to be easily removable under ether. The patient was well 6 months later, when last observed. Shield cites a patient, aged 45 years, who, when operated upon for primary spindle-celled sarcoma of the breast, nearly died of hemorrhage at the first operation. The disease recurred a number of times and was operated upon.

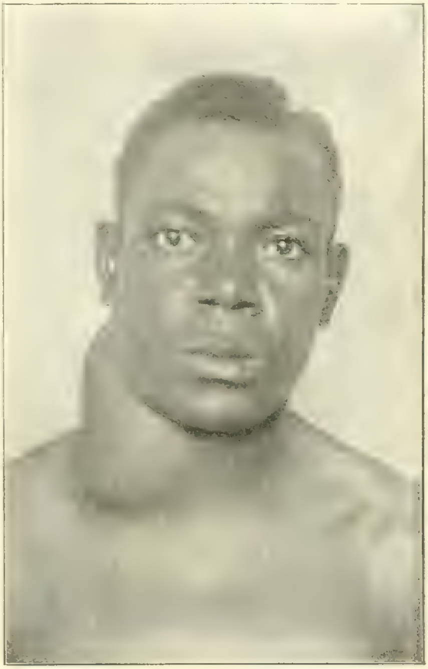

Fig. 1109.—Lympho-Sarcoma of Neck. Removed by operation.

The patient finally died, at the age of 74, of extensive local recurrence.

Careful microscopical examination of the tissues surrounding sarcoma of the soft parts shows that infected cells are found at considerable distances beyond the substance of the tumor, both along the fascia and in the bundles of muscle fibres themselves. If we are to improve the results of operative treatment of sarcoma of the breast, we must abandon the old idea that sarcoma is an encapsulated tumor that can be easily shelled out, and must operate on lines similar to those we have adopted in dealing with carcinoma, *i.e.*, remove wide areas of healthy tissue beyond the apparent limits of the tumor.

Melanotic Sarcoma.—This form of sarcoma was described by Laënnec as early as 1806 under the name of melanosis, a term which he applied to all varieties of pigmented cancer. Virchow later divided these pigmented tumors into melanoma, melanotic carcinoma, and melanotic sarcoma. Most of the melanotic malignant growths were at first regarded as carcinomas, but in recent years there is a growing tendency to class them as sarcomas.

One of the most valuable papers on melanotic neoplasms is that of Ebermann, of St. Petersburg (*Deut. Zeit. f. Chir.*, vol. xliii., Heft iii., S. 498). He has collected all the cases observed at Koenig's hospital and private clinic at Göttingen, since 1889—15 in number. To these he has added 15 cases observed at the same clinic prior to 1889 and published by Zimmerman. Of these 30 cases, 26 were sarcomas and 4 carcinomas. All of the cases of carcinoma occurred in the rectum. The round-celled type predominated. Of the later series of 15 cases, 12 were round-celled and 3 spindle-celled. In 20 cases of Ebermann's 30 cases the origin of the growth was in the skin, 7 of which began in congenital pigmented warts. Of Eiselt's large collection of 104 cases, 47 originated in the eye and 40 in the skin.

Melanotic sarcoma may occur at any age, but is most frequent between the ages of 40 and 60 years. I have personally observed 22 cases of melanotic sarcoma. In 11 of these cases the starting point was in a pigmented mole, and in 7 of these cases it developed shortly after some form of trauma (in 4 cases after tying off the mole with a thread), or of local irritation. In 17 of my 22 cases the lymph glands were affected, usually those nearest the primary tumor. In more than one-half of my cases there was rapid generalization of the disease. In one case in which an autopsy was made, metastases were found in practically every organ.

Treatment.—Although rapid recurrence with a fatal issue after a varying interval of a few months to two or three years is the usual history of cases treated by operation, there are a few authentic cases of cure. In my article on sarcoma ("Twentieth Century Practice of Medicine," vol. xvii.), I cited 2 cases well 9 and 11 years after operation. Hence I believe it justifiable always to operate on primary melanotic sarcomas. Operations in these cases should be very extensive and should remove wider areas of skin than has hitherto been the custom. The nearest lymph glands should always be dissected out, whether enlarged or not. In a number of cases in which the prognosis was very bad, I have used, with every precaution, the erysipelas toxins, but with little apparent effect.

Some Recent Methods for the Treatment of Inoperable Cancer.

During the last few years several methods for the treatment of inoperable cancer have been introduced and advocated by distinguished men.

Treatment of inoperable cancer by means of ovariectomy combined with administration of thyroid extract was first used by Dr. George Beatson (*Lancet*, 1896, 62–104). Two or three cases were reported in which the thyroid extract was employed as an adjunct to the operative removal of the tubes and ovaries. Beatson's published cases are of great interest. Some of them undoubtedly show great improvement, but none has remained well sufficiently long to justify one in considering the disease cured. This method was taken up by a number of well-known English surgeons, notably Mr. Watson Cheyne, who reported two cases with marked improvement in one and little effect in the other. Beatson's conclusions were: "We must look in the female to the ovaries for the exciting cause of carcinoma, certainly of the mammary organs." This would seem in general to be a pure hypothesis entirely unsupported by facts. It would seem to me that the important trophic changes that have been noted after removal of the ovaries in cases thus far observed can be fully explained in a much more simple way without the necessity of elaborating a new theory as to the origin of cancer. The explanation that I would offer is that the changes were brought about simply by diminished vascularity of the breast resulting from the ovariectomy which diminishes the blood supply of the tumor, which in nearly all cases is followed by at least temporary diminution in its size and general improvement in its symptoms. The administration of the thyroid extract has in a certain number of cases been followed by a temporary improvement. I have myself used thyroid extract in a number of cases without any apparent change. I do not think that the results of oöphorectomy thus far offer sufficient encouragement to justify a general adoption of the method.

Injections of Alcohol.—This method, first advocated by Schwalbe and Hasse in 1872, and recently revived by Kuh, of Chicago, gives little promise of success in inoperable cancer.

Ligature of Arteries or Cutting Off the Blood Supply.—Ligature of the arteries giving nutrition to the tumor is said to have been introduced by Harvey in 1651. It has been much used in non-malignant tumors of the thyroid. Ligature of the carotid for malignant tumors of the pharynx has been tried in a number of cases, but usually only with slight temporary benefit. Dr. J. D. Bryant, of New York, has reported a case of inoperable nasopharyngeal sarcoma which disappeared after ligation of both external carotid arteries, the patient remaining well for nearly ten years afterward. Several other similar cases treated by this method showed only temporary shrinkage of the tumor. Dr. R. H. M. Dawbarn, of New York, believing that the simple ligature of the external carotids does not sufficiently cut off the nutrition of the tumor, has described a method which he designates as excision of the external carotid arteries, which he advocates in inoperable malignant tumors in those regions deriving their blood supply from these arteries. Simple ligature of the external carotid, even in the hands of skilled surgeons, has been hitherto attended by considerable mortality. This, however, should not make one hesitate to advocate the procedure in hopeless, inoperable cases of cancer, provided the results are sufficient to warrant the risk. The operation advocated by Dawbarn consists in tying the external carotid just above its origin. The artery is then caught with forceps, tied, and cut; the proximal end is grasped with an artery forceps. Then, by working upward, each branch is tied off between two ligatures and divided as reached.

The latest results of this method (as stated in a communication just received from Dr. Dawbarn) are as follows: 14 patients have been operated upon by Dawbarn and 9 by other men. He states that there have been but 4 deaths that could with fairness be attributed to the operation, thus showing a mortality of 17.4 per cent. In regard to the actual value of the operation, based upon the number of cures or the duration of life following the operation, this cannot at present be accurately estimated. Dawbarn states that all but 2 cases have been hospital cases and difficult to trace. In the spring of 1900 Dr. Dawbarn presented 5 patients before the New York Surgical Society, operated upon between 1895 and 1898. He states that all of them were either carcinoma or sarcoma cases, the diagnosis having been confirmed by pathologists. One patient with round-celled sarcoma of the naso-pharynx was well 5 years and 6 months after operation. A second patient operated upon April 18th, 1896, with sarcoma of superior maxilla, was well 4 years after operation. In none of the cases did the tumor entirely disappear. These results would seem to prove that, in a certain percentage of cases of malignant tumors deriving their blood supply from the external carotid arteries, the disease is temporarily held in check and life prolonged. Whether any of these patients have been actually cured cannot be determined until a longer time has elapsed. I believe that in most of the cases the relief will prove temporary. Until the after-history of the patients already operated upon has been carefully traced, I do not believe the operation should be generally adopted

The Treatment of Cancer by Cataphoresis, originally proposed by W. J. Morton, of New York, is strongly advocated by G. B. Massey, of Philadelphia. His latest results may be found in *The Medical Record* of April 7th, 1900. He states that he has used the method in 37 cases, of which 7 were operable and 30 inoperable. Of the operable cases 4 were cured and 1 probably cured; 2 were failures. Of the inoperable cases, 6 were cured; 2 probably cured; probable failure in 2; complete failure in 20. Of 37 cases 10 were cured, 7 were doubtful, and 22 were regarded as failures. While many of the cases were recent, in several the freedom from recurrence extended over more than 3 years. One case, an epithelioma of the cervix uteri, was well 3 years and 6 months; 1 case of sarcoma of the soft and hard palate was well 6 years. Another case of sarcoma of the upper jaw remained well 2 years; in 2 cases death occurred during application.

I do not deem that the method should be advocated in cases removable by operation. If, however, 6 cases in 30, or even a much smaller number of inoperable cases were cured, the method is certainly worthy of a more thorough trial. The duration of the so-called cures is manifestly too short at present to permit of estimating percentages accurately.

The treatment of cancer by means of *x*-rays, or with liquid air, is at present in the experimental stage, and no results have thus far been obtained to warrant the hope that these agents offer any better means of dealing with malignant tumors than do the older and more familiar methods.

The Treatment of Inoperable Cancer by the Mixed Toxins of Erysipelas and of Bacillus Prodigiosus.—The results of this method during the last two years have given me no reason to change the conclusions expressed in an earlier paper, and I have nothing new to add in the way of improvement in technique or of preparing the toxins. While the results are far better in spindle-celled sarcoma than in any other form, a sufficient number of round-celled sarcomas have been successfully treated to make it advisable to give every patient with inoperable sarcoma the benefit of a brief trial. If no improvement has occurred at the end of three or four weeks of daily injections, the treatment is not likely to be successful. If improvement does occur, the treatment should be kept up, either until the tumor has entirely disappeared or until it has become evident that the injections have lost their inhibitory influence. The toxins may be given for long periods in moderate doses without harm to the patient. The after-history of my own successful cases may be found in the June, 1900, number of the St. Paul *Medical Journal*. The risks of the treatment are practically *nil*, if proper precautions are observed. In upward of 200 cases I have had but 2 deaths, both of which occurred more than four years ago. It should be remembered that the method is advised only in inoperable sarcoma; in other words, in the entirely hopeless cases. The percentage of probable cures depends largely upon the type of cell, varying from perhaps 3 or 4 per cent. in the round-celled to nearly 50 in the spindle-celled variety. The most promising field for the employment of the toxins is, I believe, the adminstration of small and safe doses directly after primary operation, without waiting for the recurrence to appear. If the toxins can, in a considerable number of cases, destroy or permanently cure large inoperable tumors, it is quite reasonable to suppose that administration after operation would destroy the invisible portions left behind, and in a considerable number of cases prevent recurrence.

Method of Preparing the Toxins and Technique of Administration. The preparation that I have used the past three years is the one described in my last paper, viz., the mixed, unfiltered toxins of the streptococcus of erysipelas and the bacillus prodigiosus, made from cultures grown together in the same bouillon and sterilized by heating to 58° C. In children and patients much reduced in strength I have used the filtered toxins prepared by passing the mixed living cultures through a porcelain filter. This preparation is much weaker than the unfiltered, the relative strength of the two being about as 1 to 10 or 15. The effect of the filtered solution upon the tumor is less marked than that produced by the unfiltered. In the earlier cases the toxins were made from cultures of streptococcus of erysipelas obtained from a fatal case, but during the last three years a sufficiently high degree of virulence has been obtained by frequently passing the cultures through rabbits. This increase in virulence has been, I am convinced, a direct factor in the success of the toxins, and, in fact, it was to increase the virulence of the erysipelas cultures that, in 1892, I first combined the bacillus prodigiosus with the streptococcus of erysipelas, Roger, of Paris, having proved that the latter germ had the power of making the streptococcus more virulent in rabbits, though, so far as I know, it had never been used in the human body, nor had the combination ever been suggested in connection with the treatment of malignant tumors.

I am quite convinced that the process of degeneration of tumor tissue is greatly increased by the prodigiosus toxin. Many opinions have been expressed as to the nature of this process, by means of which a cure is effected. The aim should be not to cause too much depression, for in that case the patient is unable for some time to stand even small doses. Many of the successful cases steadily gained weight during the treatment, which disproves the statement of some writers that the treatment is exceedingly depressing and causes rapid emaciation. This may be true if the doses are too large, but not when the method is judiciously carried out. Strychnine may cause speedy death or act as an excellent tonic, according to the dose administered.

Aseptic Precautions. Inasmuch as the administration of these as well as other toxins undoubtedly increases the liability to infection if pathogenic germs are present, too great caution cannot be exercised in sterilizing the hypodermic needle and the skin. If a tumor be ulcerated or broken down, great efforts should be made to keep the parts aseptic. Lack of such precautions has certainly been the cause of death in a number of the fatal cases.

Duration of Treatment. Fortunately it is possible in most cases to tell in a comparatively short time whether or not the toxins are likely to be effective. If no beneficial results are apparent after four weeks' treatment, I believe it useless to continue the injections. In nearly all my successful cases marked improvement was seen within a week after the first injection, though final cure required in some cases several months of treatment. In one case, one of inoperable spindle-celled sarcoma of the abdominal wall, the tumor entirely disappeared under thirty injections and the patient is now well, one year and a half later. The question of danger of long-continued injections of the toxins is an important one. One patient with thrice recurrent rapidly growing carcinoma of breast and axilla had the toxins steadily for two and one-half years. The doses were moderate, seldom producing a chill, and averaged two a week. The tumor disappeared. The patient gained ten pounds in weight and her general health was perfect. The tumor finally recurred, ran a rapid course, causing death in six months.

Final Results in Cases Treated Previous to 1899. Of 21 successful cases treated prior to 1899, the final results are as follows: One patient with inoperable, spindle-celled sarcoma of the neck and pharynx, treated with living cultures of streptococcus of erysipelas, for four months, during which time one severe attack of erysipelas occurred, was in good health 6 years after treatment. The tumor in the pharynx did not entirely disappear, but the malignancy was evidently destroyed. Five patients were well from 6 years to 8 years after treatment. Of these, 3 were afflicted with inoperable spindle-celled sarcoma, one with round-celled sarcoma, and one with epithelioma. In all of these cases the diagnosis was confirmed by the microscopical examination of well-known pathologists. The history of one of the patients is of the greatest interest. The original growth, a very extensive infiltrating, spindle-celled sarcoma of the chest wall, entirely disappeared under four months' treatment with the toxins in 1894. After remaining well for 6 years, a similar growth has recently developed on the opposite side in a corresponding locality. The patient is again under the toxin treatment and is showing improvement.

Fifteen of the 21 cases remained well for a period of from 3 years to 7 years and 6 months. Of these, there was recurrence in 2 after 3 and 6 years respectively, 1 dying of metastases in the abdomen, the other being the case referred to as now under treatment.

The cases were all hopelessly inoperable, and the diagnosis was confirmed by the microscope except in two cases. In these two instances the history of the cases with the clinical appearances made the diagnosis of sarcoma unquestionable. The type of tumor in the 15 cases that passed the 3-year limit was as follows:

Spindle-celled sarcoma	8
Round-celled sarcoma	2
Mixed-celled sarcoma	2
Epithelioma	1
Clinical diagnosis only	2

It is worthy of special note that 2 of the successful cases now well, 3 years and 9 months and 4 years and 3 months respectively, were sarcoma of the parotid gland. Butlin, in his last edition of "Operative Treatment of the Parotid Gland," states that, "up to the present time there are very few instances of cure by operation of undoubtedly malignant disease of the parotid." In my 2 cases treated by the toxins the diagnosis was not only confirmed by a competent pathologist, but further by a history of repeated recurrences after operation. Another case still is also worthy of special mention, inasmuch as it shows that the toxins may be taken for long periods of time without harm. The patient, a well-known physician, with eight times recurrent spindle-celled sarcoma of the soft parts of the chest (anteriorly), was treated with small doses of the mixed toxins with varying intervals of rest for upward of two years. The patient regained his usual health, and has now been perfectly well over 6 years from the beginning, and 4 years since the cessation of the treatment. The tumors, while originally pure spindle-celled, were becoming more mixed with round cells and more vascular with each recurrence; in other words, the disease, as so often happens, was increasing in malignancy until the toxins were begun.

In addition to these 15 cases that have passed the 3-year limit, I have had 8 others in which the tumors disappeared. One, a spindle-celled sarcoma of the abdominal wall, was well 1 year and 6 months, when the patient returned to her home in Europe and was lost sight of. One, an extensive round-celled sarcoma of the iliac fossa, was well 1 year and was then lost sight of. A third, a spindle-celled, recurrent sarcoma of the leg, is now in perfect health, without recurrence, nearly two years after treatment. A fourth, a twice recurrent, spindle-celled sarcoma of the palm of the hand, disappeared and the patient remained well 2 years and 6 months, when the tumor recurred. Refusing amputation of the arm, she was under the care of a Christian scientist for 8 months, during which time the tumor in the hand reached the size of a cocoanut and extended above the elbow. I then amputated the arm just below the shoulder-joint, but she died of metastases 3.5 months later. Though the patient was an especially intelligent girl twenty-two years of age, while under the Christian Science treatment she watched a small tumor, the size of an English walnut, grow to the size of a cocoanut, and yet was made to believe it was actually getting smaller and improving. She also stated that she felt no pain. This is a good illustration of the utter impossibility of placing any value upon personal statements of patients in regard to improvement or cure of malignant tumors by Christian Science.

A fifth case, a chondro-sarcoma of the ilium, of large size, disappeared, and the patient after remaining well for 7 months, had a recurrence which proved fatal in about 1 year's time. A sixth, a round-celled angio-sarcoma of the breast, was well 6 months later, when the patient was lost sight of. A seventh, a recurrent fibro-angioma of the lip, was well when last heard of, over two years after treatment; and an eighth, a recurrent, spindle-celled sarcoma of the thigh, disappeared, but the patient, after remaining well for a year, had a recurrence locally and in the groin, which no longer yielded to the treatment.

In addition to these 23 personal cases, I would mention 2 other cases in which I directed the treatment, although it was carried out by other surgeons. One case (Johnson's), a large-spindle-celled sarcoma of the pharynx, entirely disappeared, and the patient was well more than 6 years later. The second (Storrs and Griswold's), an inoperable sarcoma of the breast and axilla, disappeared under seventy-eight injections of the mixed toxins, and is now well more than 4 years after treatment. The diagnosis in both of these cases was confirmed by microscopical examination, in the latter case by the highest authority in this country, Prof. William H. Welch of Johns Hopkins University.

William B. Coley.

CANCRUM ORIS. See *Mouth*, etc.

CANELLA BARK.—*Canella Alba. Wild Cinnamon.* The bark of *Canella alba* Murray (fam. *Canellaceæ*). This is a handsome, middling-sized, spicy, evergreen tree, with thick, shining, aromatic leaves and small, purple, deliciously fragrant flowers. The bark of the smaller branches is silver-gray. It is a native of the West India Islands, especially of Jamaica, Cuba, and the Bahamas, and also of the southern part of Florida. The bark of this tree was first made known in Europe in the early part of the seventeenth century, and since then has been in continuous but very limited demand. It has been frequently confounded with Winter's Bark (*Drymis Winteri* Forster), and with *Cinnamodendron corticosum* Miers. It is now very little used excepting in its home, where it is highly esteemed, more as a condiment than as a drug.

Before the bark is collected, the limbs are generally beaten all over, in order to loosen the outer layers, which are discarded, and then the inner portion is separated in quills and chips and dried. It comes in broken quills, sometimes 30 or 40 cm. long and .5 thick (12 to 15 in. by ¼ in.), but averaging much smaller, say from 5 to 10 cm. long by 2 or 3 mm. thick; the outer surface is roughish and bright buff-colored, the inner smooth or finely striated, yellowish or creamy white; fracture short and granular, odor rather agreeable, cinnamon-like; taste pungent and bitter. It contains numerous large oil cells, especially in the outer portion.

The leading constituent is the *essential oil,* of which it contains from three-fourths to one per cent. It is a composite oil, capable of being separated into several, one of which is *eugenol,* the leading ingredient of oil of cloves. With this there is some cineol. A considerable percentage of mannite can also be separated. The bitter principle needs further study. Canella is a stimulant tonic, similar to other aromatics, over which it appears to have no other advantage than the possession of a bitter principle. It is not poisonous, and is seldom given alone, in doses of .5 to 2 gm. (gr. viii. to xxx.).

W. P. Bolles.

CANITIES, or *grayness of the hair*, may be congenital or acquired, partial or complete.

Congenital canities usually occurs in the form of tufts, but may occur as round patches. This form of canities is rare. In some families it is hereditary, a white tuft of hair occurring in a large number of their members. General congenital canities is part of that general absence of pigment that is known as albinism.

Acquired canities is the form most often seen. It usually begins at about thirty-five years of age, but in some families and under certain circumstances it may begin much earlier. Beginning in early life, it constitutes premature canities; beginning at middle life, it is one of the changes incident to growing old. Few people reach fifty years of age without some gray hair.

The hair on the temples is most often that which first changes color, though there is no definite rule as to where the disease first appears. The beard may be first affected, but usually it is affected secondarily to the scalp hair. The pubic and axillary hair may escape all change in color, though at last they, too, generally are affected. When once grayness begins it is slowly or rapidly progressive. Exceptionally and rarely the normal color may return to gray hair, just as it is possible to have a third set of teeth. The change in color takes place first at the root of the hair. As the pigment becomes more and more deficient the color of the hair slowly changes from gray to a creamy or snowy white. In most cases the change in color is the only change that the hair undergoes. Alopecia may set in, but it bears no definite relation to change in the color of the hair.

Too many well-authenticated cases are now on record to allow of doubt as to the sudden occurrence of canities, over night in some cases. Such instances are almost always in relation to severe mental shock, such as the reception of some fearful intelligence.

Ringed hair is a peculiar and rare form of canities in which the hairs are marked by alternate rings of white and normal color. The diameter of the hairs is unchanged. The white rings are narrower than the colored ones. Very few of these cases are on record.

ETIOLOGY.—Canities is due to an interference with the pigment formation in the hair papilla. The gray color is the combined result of a deficiency of pigment, the presence of air bubbles between the cells of the cortex, and the essential color of the hair. When the hair is white there is no longer any pigment in the hair. The occurrence of sudden blanching of the hair is due to the entrance of air bubbles between the cortical cells. That air between the cells is one factor in causing a gray color is shown by placing a gray hair under the receiver of an air pump and exhausting the air. It will be seen that the hair regains its normal color to a greater or less extent.

Age, heredity, nervous shock or strain, neuralgia, injury to the scalp, and all debilitating diseases, are predisposing causes of canities. There is no adequate explanation for the occurrence of ringed hair.

TREATMENT.—Nothing can be done for most cases of canities. If it is due to some removable cause the color may return when the cause is removed, but no promise of this should be made. Jaborandi and acetic acid seem to have some influence on the color of the hair, and may be tried, the first internally and the last externally. Hair dyes should never be advised. Once used they must be persisted in. Many of them are harmful, especially those containing lead.

George T. Jackson.

CANNABIS INDICA.—*Indian Cannabis. Indian Hemp.* "The flowering tops of the female plant of *Cannabis sativa* Linn., grown in the East Indies" (U. S. P.). "The dried flowering or fruiting tops of the female plant of *Cannabis sativa* Linn., grown in India, from which the resin has not been removed" (B. P.).

Cannabis sativa is indigenous to Central Asia, but has been cultivated throughout Europe and America for its valuable fibre, from which hemp is manufactured. It is a member of the order *Urticaceæ*, and allied, botanically, to the common hop plant *Humulus lupulus* Linn. The United States Pharmacopœia has adopted the name Indian cannabis, as the name of Indian hemp is often given to a native plant, *Apocynum cannabinum* Linn., which is entirely different and bears no botanical or therapeutic resemblance. *Asclepias incarnata* Linn. is also popularly known as white Indian hemp.

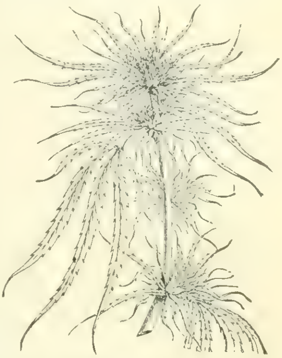

FIG. 1110. -The Hemp Plant—Pistillate Inflorescence. (Baillon.)

Cannabis sativa is a large, very variable, annual herb, with an upright, slender, usually branching stem from 1 to 3 metres high (3 to 10 feet), long-petioled, graceful, palmately divided leaves, and small, clustered, diœcious flowers. The bark of the stems and branches has an exceedingly tough fibre. The leaves are opposite (or alternate above), stipulate, and consist of from five to seven (excepting near the top of the stem, where they are simpler) linear-lanceolate, pointed, sharply serrate leaflets. Flowers in axillary clusters. In the staminate on male plant the flowering top is in lax, spreading, or drooping panicles, consisting of five sepals and as many opposite, large-anthered stamens. In the female plant it is in small, erect spikes, each flower in the axil of an upright, pointed bract, consisting of a single one-seeded, two-styled carpel enveloped in a broad, spathe-like, one-leaved perianth. Fruit (the hemp seed of commerce), a roundish-pointed achenium containing a single pendulous, oily seed.

The plant contains a large amount of resin, which exudes upon the surface of the plant, more particularly upon the flowering branch. This resin becomes most abundant at the period of fructification, and as the fruit forms it diminishes in a very marked degree. During cultivation any loss of resin is prevented by eliminating the male plants or by gathering the tops before the fruit begins to form. In temperate climates the plant is almost destitute of resin, and for medicinal purposes that which is grown in India and Southern Asia is alone utilized.

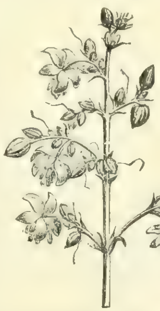

FIG. 1111. Staminate Inflorescence of the Same. (Baillon.)

Indian hemp is collected in three forms: first, the flowering tops of the female plant, known as "gunjah," which we recognize officially in the Pharmacopœia; secondly, the leaves, "bhang," which are used for smoking; and, thirdly, the resin, "churrus," or "charus," which enters into the composition of "hashish," and is also used for smoking.

The tops as they reach us consist of compressed masses of branches and leaves with flowers, and at times with specimens of immature fruit, the whole matted together by the resinous secretion. The leaves and bracts bear external oleoresin glands, and one-celled curved hairs, which are very characteristic and serve to identify the plant. The bases of these hairs are enlarged and frequently contain cystoliths. The tops have a greenish-brown color, a narcotic odor, and a slightly acrid taste. The medicinal value of the plant varies greatly and is very uncertain. This, in a measure, is due to climatic influence and the period of collection; but it is also accounted for by the time that has elapsed since the plant was collected and by its mode of preservation. Experiments have shown that the plant diminishes in strength, after a period of six months, when exposed to the air; while control specimens, which are kept in air-tight bottles, still remain active. A gradual oxidation of the resin is the supposed cause of the change.

Our knowledge of the active principles of the plant remains very uncertain. The resin as originally separated by T. and H. Smith, of Edinburgh, in 1846, and named *cannabin,* is still accepted as representing the active principles, and is almost entirely employed for medicinal purposes. It forms the solid extract of the Pharmacopœia, and the fluid extract and tincture are alcoholic solutions. In 1857, Personne described *cannabene,* a volatile oil, which for some time was thought to be the active ingredient. It has, however, proved to be an impure sesquiterpene, and of no therapeutic value. An alkaloid resembling nicotine has been found at different times, but it never has had the characteristic action of cannabis.

Cannabin tannate is a preparation manufactured by Merck. It is introduced as a very reliable narcotic and devoid of all volatile and toxic principles.

During the last few years cannabis indica has been very thoroughly studied by Professor Marshall and his assistants, in his laboratory at Cambridge University. As an outcome of their investigations there has been produced a red oil to which they have given the name of *cannabinol,* and the chemical formula $C_{18}H_{24}O_2$. This they consider to represent the active properties of the plant, but their labors are not completed, and the comparative therapeutic value of the new compound is as yet uncertain.

Cannabis indica is much used by the natives of India, Arabia, and neighboring countries as an intoxicant. For this purpose the dried leaves and the resin are smoked, either uncombined with other ingredients or mixed with tobacco. In Arabia the resin is combined with opium and other narcotics to form the well-known "hashish." In some instances a decoction is made from the leaves and employed as a beverage to induce the intoxication. The effect produced is an inebriation of an agreeable character, exciting the individual to sing and laugh. There are pleasant and often gorgeous visions and hallucinations, with a sense of ecstasy, and more or less delirium, terminating in a deep sleep. The sleep may be cataleptic in character, the muscles being slightly contracted and the limbs pliable. Later observers have described a condition resembling hypnotism. During the intoxication the sexual propensities of the individual are stimulated, which has established its reputation as an aphrodisiac.

The craving for this stimulant is very prevalent among the Asiatics, and many who are addicted to its use are more or less continually under its influence.

The effect produced by cannabis indica varies according to the mode of administration. When the fumes are inhaled it is a stimulant and intoxicant. Its effect begins early, and if but a small amount is used, it passes off in half an hour or more. If it is taken into the stomach its action is slow, an hour or two elapsing before the drug is absorbed. In this way its stimulating effects are much less marked, and its depressant and narcotic action is more evident. As an anodyne and antispasmodic it is classed by many as ranking next to opium. In large doses it produces the same effect as when inhaled. Experimental work has shown that the primary stimulation rapidly passes and is followed by depression, loss of reflexes, ataxia, diminished sensibility, a tendency to sleep, and stupor, with a certain degree of anæsthesia and paralysis. The effect upon the heart and respiration is not a prominent symptom. The early stimulation continues for some time, and the depression of respiration and circulation becomes marked only as narcosis begins. The mode of death is uncertain, some observers reporting that death takes place from cardiac failure, while others state that the heart was observed to beat after the respirations had ceased. Upon the kidneys it exercises no direct action, but the tendency is to increased excretion of urine. It is stated that a decoction of the fresh plant is an active diuretic. No specific action upon the sexual organs has been detected, excepting that accompanying the general stimulation. Cannabis indica is not a dangerous drug. The physiological effects may be very marked, but to cause death a very large amount would be required. No authentic instance of its fatal effects has been recorded. In animals it is found that, of the fluid extract, ♏ x. will cause marked symptoms, but as much as ℥ i. is required to produce death.

The therapeutic value of Indian hemp is due to its influence on the nervous system, and by some it is supposed to act directly upon the cerebral cells. Its sedative effect is most valuable in functional disorders and in pain not due to inflammation. It has proved of value in the aged when the mental faculties are weakened generally and when much restlessness and sleeplessness are prominent symptoms. In doses of gr. ¼ to ⅛ at bedtime a calm and quiet sleep is secured, and the same action may be secured for weeks without increasing the dose. In melancholia and chronic alcoholic delirium of the aged, accompanied by depression, it has acted as an exhilarant, has produced the desired sense of strength, and has secured quiet and rest. In the restlessness of general paralysis and "temper diseases," in both adults and children, it has also been of the greatest service.

In painful maladies it has acted best in those of a functional character, such as neuralgia and migraine, either alone or when combined with constitutional remedies, as iron, quinine, and zinc, when such are indicated. In neuritis it proves of service only when given in addition to mercury, iodine, and other such remedies. It has also proved very serviceable in the formication, tingling, numbness, and other sensory disturbances of the elderly and gouty.

It has been very successful in clonic muscular spasms such as the convulsions of children and adults due to reflex causes, in epileptiform convulsions due to organic disease of the central nervous system, and in cases of brain tumor accompanied by convulsions and other indications of central irritation. In true epilepsy it has proved useless. In numerous cases it has been given for a prolonged period until its full physiological action was produced, and yet it has failed to influence the disease in the slightest degree. It relieves the distress of spasmodic asthma and has proved very serviceable in spasmodic dysmenorrhœa not associated with metritis or with other inflammatory affections. It has proved of service in chorea, whooping-cough, hysteria, migraine, and neuralgia. It has also proved of particular usefulness in painful disorders of the stomach, when not accompanied by organic changes. It has proved a better sedative than opium, as it exercises hardly any derangement of the secretions. Its beneficent effects are increased by attention to the state of the secretions, and by the employment of alkalies, purgatives, and other stomachic drugs when such are indicated.

In administering this drug the great drawback has been the unreliability of the various preparations. To obviate this, it is advisable to restrict one's practice to the use of a single preparation, beginning with a moderate dose and gradually increasing until its physiological effect is produced. Notwithstanding the various active principles that have been described, the resin and its preparations are much to be preferred. Standardized extracts, both solid and fluid, are now carefully prepared, and either these or the tincture should be employed. The dose of the solid extract is from gr. ¼ to gr. i., that of the fluid extract is from ♏ ss to ♏ i. The advantage of the fluid extract is supposed to be due to the fact that only moderate heat is employed during its preparation. The dose of the tincture is from ♏ v. ♏ to xxx. The preparations should never be added to aqueous solutions as the resin immediately separates as an insoluble mass.

Beaumont Small.

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CANNES, FRANCE.—Cannes, a winter resort on the French Riviera, is picturesquely situated in a recess of the Gulf of Napoule. It is 660 miles distant from Paris, 120 from Marseilles, 19 from Nice, and 28 southwest of Mentone. "Unlike any of the other health resorts on the Riviera, Cannes extends over a wide tract of land, so that its eastern and western limits are some miles apart, and its attractions and beauties are not limited and concentrated in one particular spot, but are varied and widespread" (Burney Yeo)

It is well protected on the east, and partially so on the west, by an isolated mountain group called the Esterel. On the north, however, the higher ridges of the Alps are too far distant to afford proper shelter. Like Nice it is a windy place, the sharp, violent, and disagreeable *mistral* (northwest wind) prevailing frequently in February and March. It is less sheltered than Mentone and San Remo, and consequently the climate is less equable. The general characteristics of the climate of this resort are mildness, abundant sunshine, moderate average rainfall, and, for the seashore, a low relative humidity. The winds and the lack of equability, particularly between the sun and the shade and the day and night temperatures, are some of the objectionable features. "The Riviera," says Burney Yeo, "is a land of sunshine and a land of winds. It is a land of intense, brilliant sunshine and of cold, chilling shade." "The deceptive combination," says Lindsay, "of brilliant sunshine with cutting blasts is the great climatic defect of the Riviera." The great and continued popularity of this, as well as of the other resorts of the Riviera, depends not so much on the intrinsic excellence of its climate, as on its comparative superiority over the usual climate of the more northern portions of the Continent and of England. Climates like pleasures are often judged by comparisons, and when, for instance, we compare the winter climate of London or Vienna with that of Cannes, the latter appears quite superlatively excellent. But if we compare the climate of Cannes with that of some resorts on the opposite coast of Africa or in Southern California, or with that of many of the resorts in our Southern States, Cannes decidedly suffers by the comparison. When, on the other hand, one considers the beauty of its situation, the variety and charm of its scenery, the richness of its vegetation, and all the fascination incident to a resort on the beautiful Mediterranean coast, Cannes surely has few superiors. It is to be borne in mind, say Burney Yeo and others, that at Cannes one can avail himself of two somewhat different climates, according as he chooses a residence in the neighborhood of the seashore or inland in the valley of Cannet, for example, about two miles distant from the sea, where greater protection for dwellings and promenades is afforded. All writers upon the latter climate refer to it as "bracing" and "exciting," with a tonic and stimulating atmosphere.

The following meteorological table arranged from Marcet's* personal observations, extending over a period of from two to six seasons, will give the reader a means of comparing this with other climates. The data are for the winter season, extending from November to April inclusive.

CLIMATE OF CANNES, FRANCE. OBSERVATIONS OF W. MARCET, M.D. (FAHRENHEIT SCALE.)

	November.	December.	January.	February.	March.	April.	Season.
Temperature—							
Mean average temp..	52.6°	46.3°	48.0°	48.8°	51.0°	55.5°	50.8°
Average daily range.	12.3	12.4	12	13.4	13.2	12.8	
Mean of warmest....	58.8	52.5	54	55.5	57.6	62	
Mean of coldest	46.5	40.1	42	42.1	44.4	49.1	
Mean maximum sun temperature........	99.7	91.6	96.1	106	114.7	120.7	
Mean lowest night temperature.......	38.4	31.4	32.2	33.8	35.4	41.9	
Precipitation—							
Average in inches ...	5.17	4.51	1.69	1.46	3.42	4.05	20.31
Wind—							
Prevailing direction.	...	....	....	....	W.	E.	E. and S. E.
Calm days...........	10.7	11.7	12.5	8.2	3	2.7	48.8
Light to fresh	12.7	13.5	13	11.7	19.2	18.5	88.9
Stormy to gale	6.2	5.7	5.5	7.2	8.7	8.5	41.8
Humidity—							
Average relative	71.2%	72.7%	71.7%	75%	73.1%	74.3%	73%
Weather—							
Fine days............	17.5	18.8	21	20	21.3	18.4	117
Overcast	2.1	3.5	3.8	3.1	2.6	1.5	16.6
Rainy	9.5	8.8	6.3	5.3	7.1	8.6	45.6
Temperature of sea....	61°	57.1°	55.7°	55.5°	56.7°	59.3°	

The climatic characteristics of the various months are summarized by Marcet as follows: "In November and December the weather is usually stormy and wet. January and February are fine, with occasional visits of the dry northwest winds. During these two months the air is usually calm in the morning with a pleasant light southerly breeze blowing in the afternoon, while a northerly land breeze commences at sunset and is continued during part of the night. March and April are windy and showery, the winds showing no particular regularity, although in general easterly with wet weather." "At night," continues Marcet, "there is a sudden accession of cold together with the increase of atmospheric moisture at sunset and continued at night; therefore the importance of the invalid being indoors before sunset." Fogs are unknown, and there is an absence of mist. Occasionally the temperature sinks to the freezing point, and snow sometimes falls. As almost everywhere else, occasionally the unexpected happens, and a very wet or very cold season occurs, "and then," says Burney Yeo, "the sufferings of the visitors are very acute, much more so than at home." There is a considerable amount of lime in the soil, which adds to the disagreeable effect of the dust, which is always an annoying feature.

Dr. J. Henry Bennet wisely warns the visitor not to expect perpetual spring or eternal summer in the Riviera. "Although there is so much sunshine," he says, "so much fine weather, such immunity from fog and drizzling rain —it is still winter. Wind, rain, chilly atmosphere, and occasional cold weather, with snow on the mountains and flakes of ice in exposed situations, have to be encountered." The Riviera is not Southern California, and a climate similar to that of the latter region must not be expected. If the reader will turn to the article upon *California, Southern,* in this volume and compare the climatic tables of San Diego and Santa Barbara with that given here of Cannes, he will realize the difference. For instance, the average mean temperature for January at Cannes is 48° F., while at San Diego it is 53.6° F., and at Santa Barbara 51.2° F. Further, the rainfall at these two California coast resorts is only about half of what it is at Cannes, and the number of fair and clear days is considerably greater, and there is also less wind. Although the relative humidity is almost exactly the same, the complete absence of fog would seem to indicate a comparatively drier atmosphere at Cannes.

It is well to emphasize again the fact of the winds;

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* "Southern and Swiss Health Resorts," by W. Marcet, M.D.

they are the *bête noir* of Cannes, as indeed of the Riviera in general. Moreover, they seem to be quite incapable of classification. "They are legion," says Burney Yeo, and Marcet declares that their direction is so changeable that it is not worth while to record them—they blow hot and they blow cold, the sirocco from Africa and the bise from the Alps. They blow dry from the west and moist from the east. Dr. Cozalis, quoted by Burney Yeo, gives his results from several years' personal experience as follows:

"Toward the last week in October, the wind sometimes from the east, sometimes from the west, becomes high. In November there is always a windy and rainy period lasting for from eight days to three weeks. The wind is rarely violent and never cold. During or after this there may be a few days of mistral; then commences the reign of the east wind, a mild wind which lasts till February. December and January are the least windy months. West winds begin again in February, and the northwest (mistral) may blow for two or three days. In March the winds are often violent, and bring not infrequently torrents of rain, as in November. In April the winds are very variable."

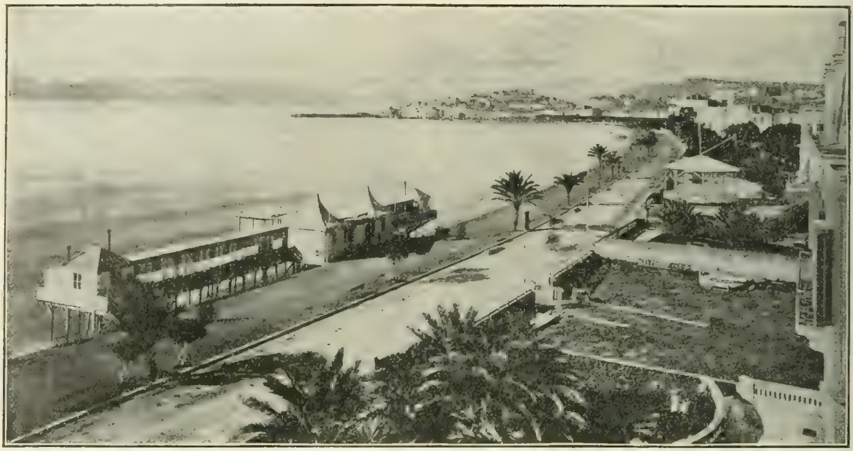

FIG. 1112.—Boulevard de la Croizette, at Cannes.

As has been previously mentioned, Cannes offers not only opportunities for residence directly on the sea, with a purely marine climate, but also situations inland said to be more bracing and less exciting, on the Californie and in the district of Cannet, where also there is greater protection from the winds. The climate along the shore is exciting and warm; inland it is more bracing and less exciting.

The class of cases which are suitable for the climate of Cannes are, first of all, tuberculous affections, especially in children. Grebner[*] writes of the favorable results obtained here with children affected with scrofula, tuberculosis of the bones, joints, and glands, rachitis, and anæmia. The Dolfus Asylum, a German institution for poor children from four to fourteen years of age, is situated here. The children come at the beginning of October and remain until the middle of May. They spend the entire day out of doors, sleep in unheated rooms with open windows, and bathe in the sea the winter through. The advantage of this location over other marine resorts upon the Atlantic and north sea coasts, for a similar class of cases, is the length of time during which the *cure* can be continuously carried out. For eight or nine months long the children can live out of doors and take the sea baths. At first the general health improves and the weight increases, and later the local conditions begin to show improvement. Nearly all cases of anæmia, of whatever age they are, are said to manifest marked amelioration at Cannes. Cases of slow convalescence from acute diseases; various chronic catarrhal affections—bronchial and laryngeal,—emphysema, chronic pleurisy; certain forms of chronic gout and rheumatism; Bright's disease and diabetes—all these are said to be benefited by a winter residence here. On the other hand, this climate is unsuitable for hysteria, neuralgia, insomnia, and various other nervous maladies, and for febrile cases from whatever cause. "All invalids," says Burney Yeo, "except those who suffer from scrofulous or lymphatic conditions, are advised to keep away from the shore."

This climate, like any other mild, sunny one, is also favorable for the feeble from age or other causes. As to pulmonary tuberculosis, the writer does not believe that Cannes, or the Riviera in general, is a favorable climate for its cure. Certain stages of it, more particularly the chronic condition, may be temporarily benefited and life prolonged, but, as Lindsay says, "after a prolonged and thorough trial of the Riviera, but few authorities report many cases of cure." Undoubtedly sanatorium treatment in this climate would show better results, but so many other more favorable localities are now known in Europe, for the strict curative treatment of this disease—such, for example, as Davos, Arosa, Leysin, Les Avants, and others—that it seems probable that the Riviera will not in the future, as in the past, remain the Mecca for consumptives. Moreover, the profession is more and more becoming convinced that it is better to establish sanatoria for consumptives at home, in the country and locality where the patients live; for almost everywhere a suitable location can be found where the air is pure, where there is an absence of high winds and dust, and where a reasonable amount of sunshine exists. These are the climatic conditions which are really essential to a cure, although with them must be united the hygienic-dietetic régime which experience has shown to be equally important if the best results are to be secured.

Cannes—derived from Cannæ, the reeds in which the fishermen's huts originally stood—has now grown to be a city of 23,000 inhabitants. It owes its prosperity in a great measure to the first Lord Brougham, who took up his residence here in 1834. It is especially popular with the English, who frequent it in great numbers. Ten thousand visitors spend the season here, and from fifty to sixty thousand pass through the town. It is almost unrivalled in the beauty of its situation and the charm of its surroundings, and has been called the "Pearl of the Riviera." There are innumerable excursions by sea and land, and the surrounding country is exceedingly beautiful. It has a rich and varied vegetation; here flourish the eucalyptus, olive, vine, orange-tree, and the myriad shrubs and flowers of a luxuriant southern growth.

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[*] Jahrbuch für Kinderheilkunde, N. F., 42, 1896, p. 284.

The accommodations are excellent, but are said to be expensive. Most of the hotels, pensions, and villas are surrounded with gardens. "One great advantage of Cannes," writes Dean Alford, quoted by Burney Yeo, "over other Riviera stations is, that you have actual forest scenery within fifty yards of your hotel." The town is abundantly supplied with good drinking water. The sanitation seems to be well looked after, and the system of supervision of apartments occupied by consumptives is so complete and thorough that it will be instructive to mention it.

When a physician has a consumptive patient occupying a room in a hotel or villa, he notifies the proprietor when the room is vacated. The proprietor takes this notification to the sanitary authorities, who disinfect the premises and return the original card of notification to the physician with a note made on it that disinfection has been made, and the physician then is assured that the room is safe for occupancy again. In addition, there is kept, at the mayor's office, a list of the hotels and villas whose proprietors have agreed to conform to all the suggestions made by the physicians as to disinfection and renovation. Whenever a physician is asked to recommend a hotel or apartment, he has this list, which is public, to refer to. This arrangement works for the mutual interests of the proprietors and visitors.

Cannes has become so popular and fashionable that for this reason it is objectionable for the true invalid; he is tempted to over-exert himself in the social life and gayety of the place. *Edward O. Otis.*

CANTHARIDATE OF POTASSIUM.—The application of the cantharidins to the treatment of tuberculosis was introduced at a meeting of the Berlin Medical Society on February 25th, 1891, by Dr. Oscar Liebreich. The value of this drug as a remedy rested on its well-known property of promoting exudation of serum from the capillaries; an effect not only directed to the vessels of the surface of the body, but also produced in various organs, as the kidneys, sexual organs, and lungs, particularly when the drug is administered internally. This is the special action of the drug on the healthy tissues, and Liebreich assumed that an irritated condition of any set of capillaries would favor this process of exudation, or, in other words, that a dose too small to produce any effect on healthy capillaries would cause an exudation from those inflamed. This would relieve the congested cells and restore the tissues to a more healthy state; and, further, he claimed, as it had been shown that serum possessed decided germicidal properties, it should prove antagonistic to the growth of tubercle and assist in the effort at repair.

A number of cases treated by Liebreich's method were shown by himself and some of his colleagues; cases of laryngeal phthisis, lupus, and pulmonary phthisis were all said to be benefited. When the diseased parts could be observed, the action of the drug was found to be such as had been described by Dr. Liebreich, the ulcerated surface being more healthy and showing signs of repair. When the lungs were affected the expectoration became free and profuse, the œdema decreased, and the local condition improved; the fever also diminished, and other constitutional disturbances lessened. Liebreich stated that no reaction followed its use, but other observers reported a slight rise of temperature, headache, disturbed digestion, diarrhœa, etc. If the dose be too great it produces the characteristic symptoms of cantharides poisoning—pains in the loins, albuminuria, strangury, and hæmaturia.

Pure cantharidin being insoluble in water, the cantharidate of potassium and the cantharidate of sodium were selected as the salts most suitable for using the drug hypodermically. As the amount of cantharidin in these salts varies greatly, Liebreich advised the use of a certain solution which he had found by experiment to be most suitable. It is prepared as follows: cantharidin, .2 gm.; potassic hydrate, .4 gm., most carefully weighed and heated over a water bath in a 1,000 c.c. flask, with about 20 c.c. of water, until a clear solution results; then add water gradually, while still heating, to the full quantity.

Of this solution ♏ viij. to xvi. are administered hypodermically. Its use should not be continued for any length of time; at least every third day should be allowed to intervene without the drug being administered.

The effect on the kidneys must be carefully watched, and the dose lessened, or its administration stopped, should any symptoms of strangury occur. In kidney disease its use is, of course, contraindicated. To overcome the painful local irritation that frequently follows at the site of injection, it has been recommended to prepare a solution containing cocaine, which prevents the pain. Two parts of the hydrochlorate of cocaine are added to one of cantharidin and two of caustic soda; this is formed into a solution, and gr. $\frac{1}{600}$ to $\frac{1}{120}$ is used as a dose. The addition of cocaine is also thought to lessen its tendency to irritate the bladder or kidneys.

This treatment was extensively applied to all forms of tuberculous disease, but it did not prove of sufficient value to warrant its continued use, and it is now rarely resorted to. It undoubtedly produces the action described by Liebreich, causing a freer exudation of serum, etc., but this does not lead to any improvement in the symptoms or tend to any permanent benefit. Post-mortem examinations of patients who have been subjected to this treatment fail to furnish any evidence of repair or beneficial effect on the disease. *Beaumont Small.*

CANTHARIS.—*Spanish Fly.* This rather inaccurate name is given to *Cantharis vesicatoria* De Geer (*Lytta vesicatoria*), order *Coleoptera*, a brilliant green beetle, with a long, cylindrical body, a disagreeable odor, and powerfully irritant properties. It is about an inch in length, and from one-fifth to a fourth of an inch in breadth. It has a good-sized, ovoid, heart-shaped head, filiform, black antennæ of eleven joints, a distinct, rounded thorax, and long, straight wing covers. The legs are provided with five tarsal joints, excepting the two posterior ones, which have only four. The wings are large, brown, translucent. The odor, even when the insect has been dried for a long time, is strong and characteristic. The perfect beetle appears in its native countries, about the middle of summer, upon poplars, ashes, lilacs, privets, and even upon roses and several other domestic shrubs, whose leaves it devours. The acrid effluvium emitted from it can be smelled at a considerable distance, and when the insects are abundant, it is said to be dangerous to persons sitting under the trees where they are.

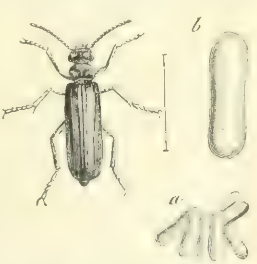

FIG. 1113.—Blistering Beetle, Natural Size; *a*, Eggs, somewhat enlarged; *b*, a single egg, greatly enlarged. (Moquin-Tandon.)

This beetle is a native of Southern and Middle Europe, Western Asia, etc. It is abundant in Spain, France, Germany, Italy, etc., and in these countries is collected for use. During the middle of warm days it is very active and alert, but in the night and early morning, benumbed by cold and wet, it is very heavy and clumsy. Advantage is taken of this time for collecting the beetles, when they can be beaten or shaken from the shrubs where they hang and caught in sheets or bags held under the boughs. They are then killed by boiling water, steam, vinegar, ether, or some such treatment, and carefully dried by moderate heat.

The drug, as usually found in the market, consists of these bodies whole, excepting what the friction of the transportation has done in the way of rubbing off the antennæ and legs. Ground, it gives a disagreeable-smelling, grayish powder, sprinkled with bright metallic green specks—the fragments of wing cases and body. Taste, resinous and acrid.

Blistering beetles were known to the ancients, and have been used for centuries in many different countries, but they have not been generally of this particular species, whose employment is comparatively modern. This, however, from its abundance, and the ease with which it can be collected, has generally supplanted the others, at least in English and American commerce.

Composition.—A great variety of ordinary animal products, nitrogenous tissues, fat, oil, watery extract, etc., and about one-fourth to one-half per cent. of a well-defined, crystalline, active principle named *cantharidin*. This energetic poison crystallizes in tables or flakes, is white, colorless, and odorless, and at first has but little taste. It dissolves in 25 parts of water, and in upward of 3,000 of alcohol; in ether and chloroform it is almost insoluble. Cantharidin is about thirty times as active as cantharides.

Action and Uses.—Cantharides is an intense irritant, whether applied internally or externally; taken into the stomach, it causes heat and burning of the fauces on its way down, then vomiting, often of bloody mucus, intense pain and burning of the stomach and bowels, diarrhœa, fibrinous and bloody stools, and finally urinary distress, strangury, bloody urine, and other evidences of renal and vesical irritation. The genitals are also excited—priapism in the male, swelling of the vulva, etc., in the female; uterine tenesmus or abortion may follow. Erotic sentiments may be, but are not necessarily, aroused. A small, quick pulse, rapid breathing, a hot, dry skin, headache, delirium, coma, and death may follow its introduction. Two grams (gr. xxx.) of powdered cantharides, or 5 cgm. (gr. ¾) of cantharidin, would be a dangerous dose. Applied externally, cantharides produces, after a few minutes, redness and slight burning of the skin, followed, in from one-half to five or six hours, by small blisters just beneath the cuticle, which rapidly separate it from the skin and soon coalesce into one large bleb over the whole surface covered by the blister. A small amount of cantharidin is absorbed through the skin, as strangury, hæmaturia, etc., are rather apt to follow very extensive blistering. This medicine, like most active substances, has been given in a great variety of conditions —vesical catarrh, gonorrhœa, dysuria, and incontinence of urine—and as a general nervous stimulant. For none of these things is it now in vogue. Externally applied, it is the safest, surest, and in all ways the best vesicant known; easy, comparatively painless, and superficial; never leaving a scar. Large and repeated blisters were formerly used, with a view of "drawing off" serous effusions from the pleura, peritoneum, the joints, etc.; but as derivative effects are not accomplished in so simple and direct a way, these blisters are now principally used as a means of producing simple counter-irritation.

Administration.—If it is desired to give *cantharides* internally, the Tincture (*Tinctura Cantharidis*, U. S. P., strength 5 per cent.) is a suitable form, but the numerous cerates and liniments which follow show how almost exclusively it is employed externally: *Ceratum Cantharidis*, U. S. P., strength 32 per cent.; and the *Collodium Cantharidatum*, U. S. P. (Blistering Collodion), containing 60 per cent., are used for blistering. The liniment, of 15-per-cent. strength, formerly official, has been discarded. For the last dozen years or more the cantharidal cerates of the Pharmacopœia have been almost superseded by a cantharidal plaster, prepared upon a large scale by manufacturing pharmacists, with a rubber basis instead of the simple fatty one of those. It is scarcely as uniform or quick in its action as the others, but on account of its convenience, its durability, and ease of handling, it is likely to continue in use. The tincture of cantharides, considerably diluted, is a frequent ingredient of "hair renewers" and other cosmetics.

Allied Animals.—The tribe *Cantharidæ* contains numerous poisonous beetles, whose acrid secretions have been put to use as vesicants. Some of these are even more irritant than cantharis itself. *C. Vittata*, our potato beetle, and other species of *Cantharis*, *Meloe*, the oil beetles, several species of *Mylabris* ("M. Chiccorii," the "Chinese blistering fly") are examples.

W. P. Bolles.

CAOUTCHOUC. See *Rubber*.

CAPE MAY.—The first point on the New Jersey coast to which people went to enjoy the ocean was Cape May. As early as the opening of the last century there were stage lines and sailing vessels which made a business of taking visitors to this resort. For many years Cape May maintained its prestige, and although at present other places have outstripped it in the number of visitors and display of fashion, there is no other place on the New Jersey coast that possesses so nearly an insular climate.

Cape May occupies the extremity of the peninsula. The ocean lies to the east and south, while the broad Delaware Bay stretches to the west and northwest. Thus nearly every breeze is from the water, and at the "Point" a land breeze is a rarity. Cape May City is built on an island three miles east of the point and faces the southeast. The underlying soil is gravel with sand under the gravel beds, and the surface wells upon which the city depends have an excellent supply of pure water. The sewerage is by means of terra-cotta pipe eight to fourteen inches in diameter; the discharge is by gentle but sufficient grades through outlets to tidal creeks. Water supply and sewerage are difficult problems at the seaside, and particularly on the low and narrow outlying strips of land on which many resorts are situated. The position of Cape May, at a latitude below 39° and nearly surrounded by water, gives it an equable climate and one of considerable humidity. The relative humidity ranges from 70 per cent. in November to 80 per cent. in July. The average for the year is 76.4 per cent.; it is thus higher than that of Philadelphia (74 per cent. at 8 A.M. and 67.8 per cent. at 8 P.M.), but lower than that of Atlantic City (94 per cent. at 8 A.M. and 81 per cent. at 8 P.M.). The mean annual temperature is 54.4° F., or 2.5° higher than that of Atlantic City. While temperatures as high as 88° F. may occur in summer, the air is quickly cooled as a late afternoon breeze from the ocean sweeps landward. The nights are usually cool and afford a grateful relief from the accumulated heat of the cities, where brick dwellings radiate heat long after the sun has set.

Comparing Cape May with Atlantic City it is found that there were in 1898 twenty-two more clear days at Cape May, but about two inches more rainfall, the excess occurring in the summer. The average mean annual rainfall, however, at Cape May is 33.12 inches against 42.81 at Atlantic City. The mean daily range of temperature is 8° F. at Cape May and 12° at Atlantic City. While the maximum at Cape May was 88°, at Atlantic City it was 94°, the minima being 15° and 7° respectively. The climate is more strictly a marine climate.

Cape May is well provided with hotels and cottages. It is freer from the objectionable crowds that throng other resorts, and the general tenor of Cape May is above that of most places on the New Jersey coast. It is comfortably reached in from one and three-quarters to two hours from Philadelphia.

Climate of Cape May, N. J., Latitude, 38° 56′; Longitude, 74° 58′.
Period of Observation, Twelve and One-Half Years.

	January.	March.	July.	September.	Year.
Temperature (Fahrenheit scale) –					
Average or normal	34.2°	40.1°	73.6°	67.9°	53.5°
Average daily range	11.8	12.6	10.7	10.7	
Mean of warmest	41.2	47.7	80	75.3	
Mean of coldest	29.4	35.1	69.3	64.6	
Highest or maximum	58	65	91	87	
Lowest or minimum	1	9	56	42	
Humidity—					
Average relative	78.2%	74.9%	79.7%	76.8%	76.7%
Precipitation—					
Average in inches	4.22	5.14	3.30	4.46	47.67
Wind—					
Prevailing direction	N.W.	N.W.	S.	E.	N.W.
Average hourly velocity in miles	14.3	16.4	10	11.7	13.4
Weather—					
Average number of clear and fair days	20	19.2	23.7	21.4	248.7
Average number of cloudy days	....	....	....	....	117

Cape May beach is unexcelled on the coast; it is broad and hard, and its descent below the water line is very gradual. The beach is, as a rule, a safe one for bathing, and at the bathing hour in midsummer presents a most animated and beautiful sight. There are times when continued easterly or northeasterly winds roll up heavy seas, and it requires a certain degree of vigor to venture into the surf. Only the most robust can enjoy the breakers at such times. It should be borne in mind that far more accidents happen to bathers of experience and over-confidence than to those who indulge moderately. After storms the gradual declivity of the shore may undergo some alteration, and bathers during a flood tide sometimes find to their consternation that between them and the shore there is a gully of deeper water than they are prepared to encounter. This is an occasional source of trouble, and even experienced bathers should never be out of reach of the bathing master and his boat.

The chief advantages of Cape May as a resort are for those who have insomnia, neurasthenia, or who are convalescing from acute respiratory affections. Children always do well, and it is a good place for those in advanced life who wish the sedative effect of the sea air. It cannot be recommended for tuberculous affections of the lungs, but the climate is not necessarily a disadvantage in chronic tuberculous disease of the bones. *Guy Hinsdale.*

CAPON SPRINGS.—Hampshire County, W. Va.

Post-Office.—Capon Springs. Hotels and cottages.

Access.—Via Baltimore and Ohio Railroad to Capon Springs Station, thence a drive of 15 miles over mountain roads to springs.

This well-known resort is situated 4 miles from the base of the Great North Mountain, at an elevation of 1,800 feet above tidewater. The scenery here is varied and pleasing, and the climatic conditions during the season, from May 15th to about the end of October, are all that could be desired. The average summer temperature is about 65° F., the mercury seldom ranging above 75° F. The main hotel is a large building, five stories in height and well supplied with modern appliances and accessories for the safety and comfort of the guests. There are two smaller hotels and a number of cottages. The main spring discharges about 12,000 gallons of water per hour, at a temperature of 66° F. An analysis by Prof. J. W. Mallet shows the following results:

One United States Gallon Contains:

Solids.	Grains.
Calcium carbonate	0.59
Magnesium carbonate	1.44
Iron carbonate	.04
Manganese carbonate	Trace.
Calcium carbonate	8.32
Lithium carbonate	Trace.
Sodium chloride	.06
Potassium sulphate	.16
Calcium sulphate	.59
Strontium sulphate	Trace.
Calcium phosphate	Trace.
Calcium fluoride	Trace.
Alumina	.02
Silica	.72
Nitrates	Trace.
Organic matter	.20
Total	12.14
Gases.	**Cu. In.**
Carbonic acid	8.56
Oxygen	1.76
Nitrogen	3.68
Total	14.00

A second spring, known as the Beauty Spring, has a similar composition.

The waters have been found of service in the treatment of gastric catarrh, the acid forms of dyspepsia, uric acid gravel, and catarrh of the bladder. A large and tastefully arranged bathing establishment is maintained at the resort. A swimming pool 98×48 feet is supplied by the main spring. Plunge, shower, douche, and warm baths may be had at the option of the visitor. The water is used commercially, and has the indorsement of many well-known Philadelphia medical men.

James K. Crook.

CAPSICUM.—*Cayenne Pepper. African Pepper. Red Pepper.* "The fruit of *Capsicum fastigiatum* Blume (fam. *Solanaceæ*)" (U. S. P.).

The species of the genus *Capsicum* are variously estimated by different botanists at from two to ninety. So extensively have they varied, and the varieties hybridized, that hundreds of forms are now recognized. The genus is probably wholly native to tropical America, but has become everywhere cultivated and naturalized in warm countries. The plants bear cultivation, as annuals, in temperate regions also, and constitute one of the important food plants of the world. Owing to its intensely hot taste, the fruit is to be regarded as a condiment rather than as a nutrient food. This is true even in the tropics, where the amount consumed at a meal is often considerable, and a matter of great astonishment to strangers. Cultivation has now developed varieties known as "Sweet Peppers," which are wanting in acridity and pungency, and which can be eaten like tomatoes and other vegetables. These products are as yet rather new, and their practical nutritive value is not yet determined.

The fruits of the many species and innumerable cultivated varieties vary in size from that of a large pea to the two fists, in form from spherical, or much broader, to long tapering, and in color from yellow through scarlet to purple. They are eaten both fresh and dried, and if carefully dried do not lose any of their pungency. The official fruit is, however, of very uniform appearance, and is thus described: oblong-conical, from 10 to 20 mm. ($\frac{2}{5}$ to $\frac{4}{5}$ in.) long, supported by a flattish, cup-shaped, five-toothed calyx, with a red, shining membranous and translucent pericarp, enclosing two cells, and containing flat, reniform, yellowish seeds, attached to a thick central placenta.

Even the medicinal article is considerably subject to substitution by other varieties. All these are readily recognized by their form and size, except when ground, when such recognition becomes a matter of extreme difficulty, the color of the powder, which is of a deep orange red in the *C. annuum*, lighter in the genuine, and the smaller size of the cells of the latter, rendering the only assistance. The powder, especially of the commercial article sold for table use, is also greatly subject to adulteration with other substances, particularly colored sawdust and cornmeal. Large quantities of the latter substance, finely ground and suitably colored, are sold for this purpose. The entire absence of tannin and starch from genuine capsicum is an important characteristic in this connection, and the ash should not exceed five or six per cent.

Composition.—Besides the active constituent, *capsai-*

cin, capsicum contains some fat, wax, resin, minute amounts of volatile oil and alkaloid, and a large amount of coloring matter.

Capsaicin ($C_9H_{14}O_2$) dissolves in alcohol and fixed oils, as well as in ether. It is so excessively acrid as to be a most dangerous substance to handle. It can be obtained in the form of colorless crystals. It should exist in capsicum in the proportion of about one-fiftieth of one per cent., and its estimation is the only sure means of ascertaining the quality of the ground drug.

"Capsicin" is merely a soft extract, consisting chiefly of resin and fixed oil, and of very indefinite strength.

Action and Uses.—Externally, capsicum is a powerful counter-irritant, capable of blistering if suitably applied. Internally, its recognized effects are due entirely to its direct and reflex stimulating action. This action is seen directly in increased movement and secretion throughout the alimentary tract, and in increased renal secretion, and reflexly in increased spinal and cerebral activity. Its aphrodisiac action is both local and spinal.

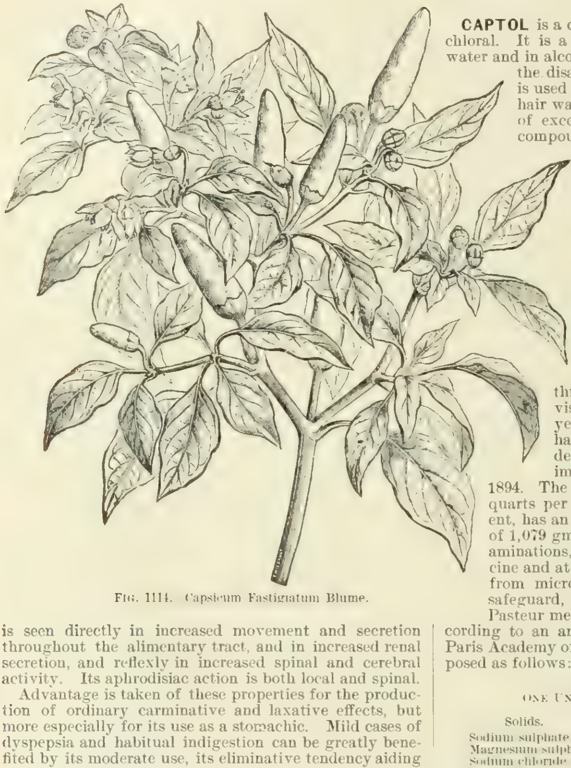

Fig. 1114. Capsicum Fastigiatum Blume.

Advantage is taken of these properties for the production of ordinary carminative and laxative effects, but more especially for its use as a stomachic. Mild cases of dyspepsia and habitual indigestion can be greatly benefited by its moderate use, its eliminative tendency aiding the stomachic effect. In extreme cases of habitual indigestion, especially that of alcoholism, it is frequently the only available agent. Its mental effects in such cases are often quite as notable as its stomachic. Its use is of assistance in overcoming narcotic habits. It has been suggested that the alkaloid of the drug may be partly responsible for the cerebral effects. As a diuretic, it is not ordinarily to be recommended, as its irritating effects are apt to be too pronounced. Throughout the tropics it is confidently recommended both as a prophylactic and as a curative agent against malaria, and it is frequently so prescribed in temperate regions also. The statement is generally made that red and black pepper have equivalent actions, but the statement is not warranted. The irritant effect of black pepper upon the mucous membrane of the stomach is much greater in proportion to its stomachic effects proper than is the case with red pepper, while the irritation of the urethra is greater with the latter. The infusion is very serviceable as a gargle in asthenic cases of sore throat.

The dose of capsicum is .05 to .5 gm. (gr. i. to v. or possibly gr. x.). The five-per-cent. tincture is most commonly employed, in doses of .3 to .4 c.c. (♏ v. to lx.). The oleoresin is given in doses of ♏ ¼ to i., and the fluid extract, ♏ i. to x. There is a plaster which contains about .25 gm. (gr. iv.) of the oleoresin of capsicum spread evenly upon a surface 10 cm. (4 in.) square.

The stronger preparations of capsicum are to be regarded as ordinary irritant poisons.

Henry H. Rusby.

CAPTOL is a condensation product of tannic acid and chloral. It is a dark-brown powder, soluble in warm water and in alcohol, and claimed to be free from any of the disagreeable effects of its components. It is used in the form of the compound spirit as a hair wash and stimulant to the scalp in cases of excessive dandruff. The formula for the compound spirit of captol is: Captol, 2; chloral hydrate, 2; tartaric acid, 2; castor oil, 1; alcohol, 65 per cent., to make 1,000.

W. A. Bastedo.

CARABAÑA MINERAL SPRING.—Province of Madrid, Spain.

Post-Office.—Carabaña.

Access.—From Madrid by rail, a twenty-minute ride.

This celebrated spring has been in active use since 1885. The location is in a country broken by sandy hills of slight elevation. It is not widely used as a resort, although a thermal establishment for bathing is maintained throughout the year. The location is best visited during the cooler months of the year. The water of the Carabaña Spring has become widely known for its valuable detergent effects. It has been extensively imported into the United States since 1894. The spring yields about twenty-five hundred quarts per day. The water is perfectly transparent, has an alkaline reaction, and a specific weight of 1,079 gm. per litre. Careful bacteriological examinations, both at the Madrid Academy of Medicine and at laboratories in Paris, show it to be free from microbic contamination. As an additional safeguard, however, the water is filtered by the Pasteur method before it is put up in bottles. According to an analysis made under the direction of the Paris Academy of Medicine, the Carabaña water is composed as follows:

One United States Gallon Contains:*

Solids.	Grains.
Sodium sulphate	7,012.89
Magnesium sulphate	214.10
Sodium chloride	112.08
Magnesium chloride	33.41
Calcium chloride	13.76
Sodium phosphate	1.47
Alumina	.03
Total	7,387.74

* Converted from grams per litre.

These findings represent the anhydrous state of the components. With the water of crystallization the weight of the solid elements would be rather more than twice that here expressed. The analysis shows a very powerful mineral water. It may be properly classed as a sodic and magnesic sulphated saline. The large proportion of sulphate of sodium combined with the sulphate of magnesium gives the water potent properties as a saline cathartic. Given in doses of a claret glassful before breakfast it secures a prompt evacuation of the bowels. As a laxative it may be given in somewhat smaller dosage, and repeated if necessary. The water has found its best application in the various intestinal, hepatic, and gastric disturbances in which constipation is a cause or a symptom. *James K. Crook.*

CARAMECUARO.—Huaniqueo, Michoacan, Mexico. A bathing establishment has been constructed at this spring. The water is hot, and it is recommended for the treatment of paludal fevers. No analysis of the water has as yet been made. *N. J. Ponce de León.*

CARAMEL.—A black, semi-liquid substance, brown when diluted, into which sugar is converted by depriving it of two molecules of water, through the application of a temperature of 400° to 420° F. It is not medicinally active, and is used as a coloring agent, chiefly for liquids, and especially for brandy and whiskey, also for leather. *Henry H. Rusby.*

CARAWAY.—*Carum.* The fruit of *Carum Carvi* L. (fam. *Umbelliferæ*). The spelling of the specific name "Carvi" is a relic of the use of but one character for both our *u* and *v*. The sound is, therefore, that of *u*, from which comes the pronunciation *caraway*. This is a biennial herb, with a long, brown, tapering, edible root, a slender, erect, branching, hollow stem, bi- or tri-pinnate leaves, with narrow linear segments, and small, compound umbels of white flowers. It is a native of Northern and Central Europe and Asia, and is cultivated and naturalized in nearly all temperate countries. The dried fruits, usually separated into their respective mericarps, are from 3 to 5 mm. long ($\frac{1}{6}$ in.), slender, slightly curved, tapering at each end, and marked with five fine yellow ribs, alternating with dark brown intervening spaces. There is one large oil tube between every two adjoining external ribs, and two between every two adjoining ventral ones, six in all. The characteristic odor and taste are familiar to nearly every one. The active constituent is carvol, which constitutes a large part of its four to seven per cent. of volatile oil, and which can advantageously be substituted for the latter. There is also some fixed oil, resin, gum, sugar, and tannin. The stimulant and carminative properties are those of the family. The odor and taste are characteristic, and make of it and its oil a favorite flavoring. It is mostly used as an ingredient of bread and cakes. The medicinal dose is .5 to 2 gm. (gr. viij. to xxx.). It enters into the Compound Tincture of Cardamomum, the only official preparation.

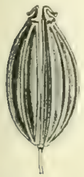
FIG. 1115.—Caraway Fruit. Enlarged about four times. (Baillon.)

The so-called "Black Caraway," also largely used by German bakers, is not at all related, being the seed of *Nigella*.

Oil of Caraway (*Oleum Carvi*).—A volatile oil existing in caraway to the extent of from four to seven per cent. It has the characteristic odor, taste, and properties of caraway. Its specific gravity is .910 to .920 at 15° C. It is soluble in an equal volume of alcohol. It consists of carvol and dextrogyrate limonene (*carvene*). The dose is ♏ i. to x., but it is preferable to use carvol. It enters into the Spiritus Juniperi Compositus, its only official preparation.

Carvol ($C_{10}H_{10}O$).—A ketone which constitutes the essential constituent of oil of caraway, and which also occurs in oil of dill and oil of spearmint. It is a colorless, or pale yellow, transparent liquid, having a specific gravity of .960 and boiling at 224° C. One cubic centimetre diluted with the same amount of alcohol should at most assume only a slightly reddish or violet tint on the addition of a drop of a very dilute solution of ferric chloride. It has the odor, taste, and properties of oil of caraway, and is, in addition, quite uniform. It is official in the German Pharmacopœia. The dose, if the preparation is pure, is 1–5 minims. *Henry H. Rusby.*

CARBOLIC ACID.—*Phenic Acid. Phenylic Alcohol. Phenol:* C_6H_5OH. This important substance, though commonly called an acid, is, properly, not an acid at all, but a member of the group of *phenols*, bodies regarded as derivates of hydrocarbons of the benzene series by the replacement of one or more atoms of hydrogen of the principal chain by hydroxyl (OH). In carbolic acid a single hydrogen atom of benzene itself is so replaced, so that this derivate is the simplest possible phenol in point of chemical constitution. Being also the best-known member of the group it is chemically entitled *phenol*, simply. Carbolic acid is an ingredient of coal tar, and is obtained therefrom. The tar abounds in phenols, and by fractional distillation and certain special manipulations carbolic acid is separable from the other constituents in varying degrees of purity. In the markets may be found pure carbolic acid, crystalline at ordinary temperatures, and impure acids of different grades, of which the best are crystalline, but the others fluid. These impure acids consist of carbolic acid (phenol) and the closely related phenol "cresylic acid" (cresol), and other phenols in admixture. The lower grades, indeed, may contain but little carbolic acid, but yet are efficient, since the other phenols of coal tar possess properties similar to those of carbolic acid. These impure carbolic acids are often sold under the name of *coal-tar creosote*, and are graded "No. 1" and "No. 2," according to purity. The United States Pharmacopœia recognizes as official pure carbolic acid, and an impure article corresponding to the "No. 1" of the fluid impure acids of commerce.

Acidum Carbolicum, Carbolic Acid (U. S. P.). By this title is designated the pure article, described as follows: "Colorless, interlaced or separate, needle-shaped crystals, or a white, crystalline mass, sometimes acquiring a reddish tint; having a characteristic, somewhat aromatic odor, and, when copiously diluted with water, a sweetish taste with a slightly burning after-taste. Deliquescent on exposure to damp air. Soluble at 15° C. (59° F.), in about fifteen parts of water, the solubility varying according to the degree of hydration of the acid. Very soluble in alcohol, ether, chloroform, benzol, carbon disulphide, glycerine, fixed and volatile oils. Almost insoluble in benzin. When gently heated, carbolic acid melts, forming a highly refractive liquid. It is also liquefied by the addition of about eight per cent. of water. If the acid be liquefied by a gentle heat, and then slowly cooled, under constant stirring, until it is partly recrystallized, the semi-liquid mass should have a temperature (remaining stationary for a short time) not lower than 35° C. (95° F.). The acid should have a boiling point not higher than 188° C. (370.4° F.). A lower boiling point, or a higher melting point, indicates a purer or less hydrated acid. When heated upon a water bath, the acid should be volatilized without leaving a residue. The vapor of the acid is inflammable. Carbolic acid is faintly acid to litmus paper" (U. S. P.).

As regards the color of carbolic acid, the tendency to acquire a pink tinge is the stronger the purer and more anhydrous the sample (Squibb). Good specimens, therefore, unless recently made, are more likely than not to be of pinkish hue. As regards the odor, it is much less rank and disagreeable than that of other associated phenols, a fact that, apart from other considerations, constitutes a good reason for selecting a chemically pure carbolic acid for surgical use. An absence of creosote-like odor is a good practical test of the purity of a given sample of carbolic acid. The reaction between carbolic acid and water is peculiar. On adding water to carbolic acid in small measure, the crystals first liquefy by the solution of the water, forming a transparent fluid. The proportion of water thus soluble in carbolic acid seems to be variable. The pharmacopœial description states that the acid "is liquefied by the addition of about eight per cent. of water," but Squibb has reported samples of pure acid dissolving as much as thirty-five per cent. of water. These saturated carbolic-acid solutions of water are fluid, and are themselves soluble in additional water only to a limited extent—between five and six per cent., according to the degree of hydration of the sample. As regards the melting and boiling points, these are affected by the amount of water that a sample may contain, and perfectly anhydrous commercial samples are rare, from two to four per cent. of water almost always being present. The congealing point is readily further reduced by a small addition of water, such as may easily occur through spontaneous deliquescence in a stock bottle frequently opened. A sample permanently fluid at ordinary temperatures is therefore not to be regarded as in any way inferior. So small an addition as that of three per cent. of water to a good commercial sample may be enough to determine permanent fluidity. Carbolic acid should be kept in well-stoppered bottles, protected from the light.

Besides carbolic acid from coal tar, which alone is official in the United States Pharmacopœia, there is commercial an article of German manufacture, prepared synthetically either from benzene or from a pure aniline oil. This synthetic carbolic acid is claimed to be exceptionally pure, but it is more expensive than the ordinary coal-tar acid.

Acidum Carbolicum Crudum, Crude Carbolic Acid (U. S. P.). This article is a distillate of *dead oil*, itself a distillate of coal tar taken between certain temperatures (165° to 190° C.). It corresponds to what was official in a former revision of the Pharmacopœia under the title *impure carbolic acid*, and to what is sold commercially as *impure carbolic acid No. 1*, and must not be confounded with what is *commercially* known as *crude carbolic acid*. According to Squibb, the products of distillation of "dead oil" are as follows: A first immediate distillate, which is the crude carbolic acid of commerce; this subjected to redistillation, yields, as secondary products, a first redistillate, highly charged with carbolic acid and the source of the purified article, and subsequently a second redistillate, coming over between the temperatures of 185° and 195° C., which redistillate, mixed with the "uncrystallizable drainings and residues" left over from the first after separation of the pure carbolic acid, constitutes the article under present consideration. It thus appears, as Squibb justly points out, that this officially so-called *crude* acid is not such in the proper sense of the word, but is properly an *impure* acid. The article is thus officially defined and described: "A liquid consisting of various constituents of coal tar, chiefly cresol and phenol, obtained by practical distillation. A nearly colorless, or reddish, or brownish-red liquid, of a strongly empyreumatic and creosote-like odor; having a benumbing, blanching, and caustic effect upon the skin or mucous membrane; and gradually turning darker on exposure to air and light. The aqueous solution of crude carbolic acid has a slightly acid reaction on litmus paper. In an aqueous solution of the acid, bromine water produces a white precipitate. Crude carbolic acid should not be soluble in less than fifteen parts of water at 15° C. (59° F.), and the aqueous solution should not have an alkaline reaction" (U. S. P.). The tests just mentioned are important for the reason that the addition of an alkali to crude carbolic acid increases the latter's solubility in water, and hence a frequent adulteration is effected by watering the acid with the solvent assistance of an alkali. Crude carbolic acid is cheaper than the pure crystalline acid, equally, if not even more, efficient as a germicide and antiseptic, but is rank and offensive in odor—the odor in this case really resembling that of creosote,—and is more irritant to animal tissues.

Besides the foregoing, other grades of so-called impure carbolic acid or coal-tar creosote are to be found in the markets, which are later redistillates from the commercial crude carbolic acid, obtained as the immediate product of distillation of dead oil, as already described. These second grades of so-called impure carbolic acid consist mainly of cresylic acid (cresol), xylol, and other phenols of a higher boiling point than carbolic acid, and contain none, indeed, of the latter substance, all the carbolic acid of the original crude substance having come over in the earlier distillations. These latter distillates, however, have germicidal and antiseptic powers similar to those of carbolic acid, and, being cheap, may be used effectively for the purposes of carbolic acid elsewhere than directly upon living tissues. "Impure carbolic acid No. 2" of commerce is a fluid, soluble in water to the extent of from forty to sixty per cent. (Squibb).

The *effects* of carbolic acid and of the other phenols associated with it in coal-tar distillates are substantially identical, so that a single description will suffice. The effects of these substances which the physician needs to note may be divided into three categories for practical study, as follows: (1) effects upon the vital endowments of bacteria and allied organisms; (2) local effects upon the tissues of the human body; and (3) constitutional effects upon the human system.

1. *Effects upon the Vital Endowments of Bacteria and Allied Organisms.*—By immersion in carbolic-acid solutions microbes may suffer temporary arrest or permanent loss of vital activity, the degree of the effect depending partly on the strength of the solution and partly on the vital tenacity of the particular organism, or even of the special stage of being of the organism under observation. To determine the exact toxic power of carbolic acid in this direction, an enormous number of experiments have been made, attacking the problem in a variety of ways. Of the more reliable of these experiments the results substantially agree, and these at the present writing justify the following broad statements: 1. Rod forms of bacteria and allied organisms soaking in aqueous solution of carbolic acid tend to suffer arrest of vital activity when the strength of the solution reaches a point between one-fifth and one-half of one per cent., and to suffer death when the strength rises to one per cent. 2. Spore forms, such as the spores of the anthrax bacillus, are much more tenacious of life, requiring for their certain killing a solution of from four to five per-cent. strength, and a soakage of from two to three days' duration (Koch). 3. Aqueous solutions of carbolic acid are far more toxic to microbes than solutions in oil or alcohol (Koch). 4. Exposure to *vapor* of carbolic acid under the conditions obtaining in practical disinfection is practically without effect upon microbes or disease germs, whether these be in rod form or spore form, and whether moist or dry.

2. *Local Effects upon the Tissues of the Human Body.*—Prudden * has observed under the microscope the effect upon living leucocytes and ciliated cells of soakage in carbolic-acid solutions, with the following results: Under soakage in solutions ranging between one-thirty-second and one-fourth per-cent. strengths, amœboid and ciliary movements slow or stop, but resume activity upon withdrawal of the carbolized fluid, and its replacement by a normal one. Under soakage in solutions of from one to five per-cent. strength, however, the bodies under observation speedily lose their power of movement, without possibility of resumption, and their protoplasm soon suffers disintegration. Applied to the human skin, comparatively weak solutions, such as the one and two per-cent. solutions used in surgery, objectively cause a whitening and shrivelling of the cuticle, and subjectively a conjoint numbness and prickling sensation, followed, if the application be prolonged beyond a few minutes, by smarting. These painful sensations Squibb declares to be aggravated by elevating, and alleviated by depressing, the affected part—phenomena contrary to those which usually obtain under circumstances of painful irritation. After withdrawal of the application the skin gradually resumes its normal appearance and tactile sensibility, recovery from the numbness, however, being slower than the return to natural appearance. Touched with the undiluted acid, the skin immediately whitens, while the circumjacent parts redden by irritation. Sharp pain, passing

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* American Journal of the Medical Sciences, January, 1881.

over into numbness, is experienced, the pain gradually subsiding after an hour's lapse, and the surface presenting the dry, scaly exudation so often seen on surgeons' hands in the days when operating under a carbolized spray was in vogue. The results of a continuous application of the pure acid are exemplified in a case reported, in which, through a misunderstanding, a finger was wrapped in cloths soaked in undiluted carbolic acid, and kept so dressed throughout a night. The next morning the dressings were removed, and on the third day, when first seen by the reporter, the tissues of the finger were found black as jet, hard as wood, wrinkled and shrivelled, cold, and absolutely anæsthetic, and with a pronounced line of demarcation between the unaffected and the mummified portion. Strange to say, however, under careful treatment the parts recovered.

3. *Constitutional Effects upon the Human System.*—Carbolic acid is very poisonous to all living things. In man, in mild poisoning, such as may follow slight absorption from carbolized dressings in surgical cases, the symptoms are restlessness and rise of temperature—symptoms easily mistaken for those of the very septic infection sought to be averted by the use of the acid; or in other cases occur headache, loss of appetite, languor, and cough, followed, if the poisoning continue, by persistent bronchial irritation, itching of the skin, dragging lumbar pains and a sense of heaviness, and want of power in the legs. In severer poisoning, such as may occur again from absorption from surgical dressings, or as will certainly result if any considerable quantity of carbolic acid be swallowed, the toxic action falls heavily upon the central nervous system. The sufferer passes rapidly into a condition of coma, with loss of reflex irritability, and occasionally, but exceptionally, with convulsions. Convulsions, however, are common in cases of poisoning of the lower animals. The breathing is stertorous, the heart's action disordered—pulse at first unduly slow, afterward rapid, and, perhaps, intermittent, and the arterial pressure diminished. The skin is covered with sweat, the lips and hands are livid, and the whole aspect is that of great prostration. When the poisoning has occurred from swallowing the acid in concentrated condition, there are added to the above symptoms burning pain, extending from mouth to stomach, experienced at the moment of swallowing, and nausea and vomiting—symptoms due to the local action of the poison upon the mucous membrane of the alimentary canal. Carbolic-acid poisoning may result in death, which may begin either at the heart or at the lungs. In such cases the lesions, apart from the local effects when the strong acid has been swallowed, are not characteristic. There is a tendency to congestion of the great viscera; the blood may seem unduly dark and fluid, and there may be some fatty degeneration of the liver and kidneys, especially the latter, but yet none of these changes are invariable.

Analysis of carbolic-acid poisoning in man and animals points to the following specific derangements as wrought by the agent: As regards the nervous system, *coma* and *convulsions*—the latter phenomenon of spinal origin—and *modification of reflex activity*, such activity being at first increased, but, later, lessened and finally abolished. As regards the *circulation*, the heart's action may at first be intensified, but, in the later stages of the poisoning, is always enfeebled. Death is frequently by cardiac failure, and the heart is commonly found, post mortem, in diastole, with flabby walls. Similarly the arterial pressure, which may be increased in the earlier stages of the poisoning, particularly if convulsions be present, notably sinks as the case progresses, apparently through paralysis of the vaso-motor centre. Upon *respiration* the action more commonly than not is opposite at the two extremes of the poisoning, the breathing at first being unnaturally rapid and shallow, whereas, later, it becomes slow, deep, and markedly stertorous. Duly devised experiments seem to show that these effects are due to a primary excitation of both the pneumogastric peripheries and centres followed by a secondary paralysis. *Body temperature*, in poisoning in the normal human subject, is variably affected, in some instances rising, in others falling, and in still others remaining unchanged. When, however, carbolic acid is administered to a fevered subject, a considerable fall of temperature may occur, accompanied by sweating. In such case the loss of heat is probably independent of any effect in that direction wrought by the sweating, since a temperature reduction has been observed in cases in which all action of the sweat glands was held in abeyance by duboisine (Raymond).

The fate of absorbed carbolic acid is obscure. Some of it is undoubtedly excreted, since it has been found by a number of observers in the urine, by Hoppe-Seyler in the saliva, and is believed by Lemaire to be present in the breath. Other portions are probably chemically transformed within the system. A result of excretion by the kidneys is to produce peculiar coloration of the urine, a fact furnishing a valuable clew to diagnosis in obscure cases of poisoning. The tint of the urine varies in different cases, in some being brownish, in others greenish-black, and in others olive green, turning a smoky black upon standing. Such urines may or may not have an adventitious odor, aromatic, or even distinctly that of carbolic acid. Exceptionally, furthermore, albumin, blood, or excess of urates may be present. These altered urines probably contain both carbolic acid under its own form and some product or products of its chemical transformation; but what these latter substances may be has not yet satisfactorily been determined.

The *therapeutic applications* of carbolic acid are utilizations of its *antiseptic, disinfectant, anæsthetic*, and *antipyretic* powers. As regards the *antiseptic* use, it is to be noted that carbolic acid is decidedly inferior in antiseptic power to quite a number of available substances, and that for surgical employment it has the positively objectionable features of strong odor, disagreeable action upon the skin, and capability of absorption to the point of producing dangerous and even fatal constitutional poisoning. For surgical purposes aqueous solutions are commonly employed, of strengths ranging from one to five per cent., the weaker for dressings to remain in contact with tissue, the stronger for occasional use or to disinfect hands, instruments, ligatures, etc. As a *disinfectant*, carbolic acid operates, of course, exclusively by its germicidal action, thus holding in abeyance or destroying, according to strength of application, the septic or infective activity that inheres in certain living protoplasms. For certainty of disinfection, as has been seen already, actual soakage of the culprit germ in a carbolic solution of at least two-per-cent. strength is essential. Dainty sprinklings of carbolic lotions are therefore futile, and the hanging about a chamber of carbolized cloths with a view to aërial disinfection by the fumes therefrom is but a noisome advertisement of ignorance or stupidity. Legitimately and thoroughly used, a two-per-cent. solution of carbolic acid is an efficient disinfectant, with the advantage of cheapness—the impure grades of the acid being for this purpose even more powerful than the pure—but with the ever-present disadvantage of a rank and even offensive odor. A solution of two-per-cent. strength does not injure textile fabrics. Carbolic acid has been given internally in the hope that the power which proves germicidal without the body will oppose within the system the career of so-called zymotic diseases. But theoretically, for this purpose, if we are to argue from the point of view of germicide action, the blood of the subject should be charged with at least one per cent. of carbolic acid, a condition involving a dosage overwhelmingly poisonous; and practically, the use of the remedy in the category of diseases referred to has been, so far, barren of important results. The *anæsthetic* action of carbolic acid is most strikingly utilizable for the relief of the pain of burns, for which purpose nothing is better than one-half or one per-cent. aqueous solution of carbolic acid applied on thin cloths—the cheap "crude" acid being here more effective than the pure (Squibb). Similar lotions may palliate also the itching and burning of skin disease or the irritation from catarrhs of mucous membranes. Thus in bronchitis the inhalation of the fumes of a bowl of boiling water charged with a few drops of carbolic acid may allay pain and cough considerably. So, again, irritability of the stomach may be quieted by this agent, and carbolic acid in small doses ranks among the standard means for arrest of vomiting. As an *antipyretic* carbolic acid is undoubtedly powerful, but its poisonousness will probably always defeat it in competition with such potent and at the same time innocent antipyretics as sodium salicylate, the cinchona alkaloids, antipyrin, etc.

For *internal administration* the dose of carbolic acid should not exceed from one to four or five drops, and the daily allowance should not surpass 1 gm. (gr. xv. or ♏ xv.). A convenient way of giving is first to dissolve in glycerine, in which menstruum carbolic acid dissolves in all proportions, and then dilute the necessary quantity of glycerine solution with water. Each dose of acid should be diluted to at least the volume of a tablespoonful for the taking. Under the title, *Glyceritum Acidi Carbolici*, Glycerite of Carbolic Acid, the United States Pharmacopœia makes official a twenty-per-cent. (by weight) solution of the acid in glycerine.

For *external uses* aqueous solutions are most generally serviceable, as already so frequently seen. There is official in the United States Pharmacopœia a preparation entitled *Unguentum Acidi Carbolici*, Ointment of Carbolic Acid, which consists of official "ointment" charged with five per cent. of carbolic acid.

Edward Curtis.

CARBOLIC ACID, POISONING BY.—Carbolic acid or phenol is one of the most common materials used for suicidal purposes at the present time. This is especially to be wondered at because of its corrosive action and the consequent pain it causes. It is, however, easily obtainable without the need of a prescription, and it does its work with certainty and generally with despatch.

Carbolic acid is a name that was given to the substance obtained from coal tar on account of its corrosive action and because it readily combined with certain basic substances to produce so-called carbolates. In its chemical relations, however, it has been shown to be closely allied to a class of compounds of the fatty-acid series known as tertiary alcohols, or, in the case of the aromatic or cyclic compounds, as phenols. It seems to unite chemically with a few bases, making compounds known as carbolates in which it acts like an acid. It also unites with acids, especially sulphuric acid, and forms salts in which it acts like an organic base.

Phenol is met with in commerce in a number of forms. First, as crude carbolic acid used as a disinfectant and germicide. This preparation is reddish or dark brown, and contains not only phenol but one or more higher homologues known as cresols. It has an odor like smoke and a strongly caustic and biting action on the skin. Secondly, as the carbolic acid or phenol of the United States Pharmacopœia, consisting of a mass of interlaced crystals, white or slightly reddish in color. These crystals are deliquescent on exposure to moist air. This phenol melts readily to a clear, oily liquid, and as it cools again becomes once more a crystalline mass. The addition of eight per cent. of water to the melted liquid prevents its solidifying on cooling. It dissolves in about fifteen parts of water, and also dissolves readily in alcohol, ether, chloroform, benzole, carbon bisulphide, glycerin, and fixed and volatile oils. Thirdly, a solution of the crystals more or less strong kept in every pharmacy as a stock material for prescription use. Fourthly, a mixture of phenol with lard and yellow wax known as *Unguentum Acidi Carbolici* (U. S. P.).

All these forms of phenol are intensely corrosive and deadly in their action. On the skin the strong phenol causes a numbness and sense of irritation or burning. The surface of the skin becomes white, the cuticle after a time falling off and leaving a dark stain. At times the sensibility of the skin is nearly destroyed by contact with the acid, a sense of numbness only being noticed.

A number of fatal cases of poisoning have occurred in which phenol has either been applied to the surface of the unbroken skin or to a mucous membrane, or has been used as an antiseptic material in treating wounds. In these cases of direct absorption the action of the phenol has been very rapid, producing sudden insensibility.

When swallowed there is at once a hot, burning sensation in the mouth, throat, and stomach. The lining membrane of the mouth is whitened by the contact of the phenol, while the lips are usually more or less brown where the liquid has come in contact with them.

The skin is dry and livid, the pulse is feeble, the pupils very much contracted, the breathing noisy, and the breath smells more or less strongly of the poison. Cases are on record, however, in which the odor has been entirely absent from the breath. At times vomiting occurs. There are usually delirium and giddiness, passing soon into a condition of insensibility. The urine, if any, is dark colored and cloudy.

Death usually occurs within a few hours, and in some instances has occurred within a few minutes.

The amount necessary to cause death is unknown. As with many other poisons, recovery has taken place after a large quantity has been swallowed and death has followed the ingestion of a few drops only.

The *Treatment* consists in the use of the stomach pump, the administration of saccharate of lime and of soluble sulphates, and, recently, very excellent results have been obtained by the use of strong alcohol after the stomach pump has taken out the most of the poison. Alcohol has proved useful also to check the action of the poison when applied to the skin. Stimulants are to be used to combat symptoms of collapse.

In fatal cases the lips where the phenol has come in contact with them are stained brown, the mucous membrane of the mouth is dirty white or brown; the stomach is contracted, and its mucous membrane in folds and white in some places, and in some spots greatly inflamed. The odor of phenol is generally noticeable on opening the stomach. The brain, lungs, liver, and kidneys usually show marks of congestion. The left ventricle of the heart is usually contracted, while the right is flaccid. The blood throughout the body is dark-colored and fluid. When phenol is absorbed by the skin there are no characteristic internal post-mortem changes.

The odor of phenol gives the best indication of its presence, but chemical tests in addition should be made to make the identification certain. To this end the material for examination is made acid with sulphuric acid and distilled. The distillate may or may not give the odor of phenol.

In a portion of the distillate place a splinter of pine wood, and on removal from the distillate moisten the splinter with hydrochloric acid. If phenol is present the splinter will turn blue or green. This test should be corroborated by a known solution of phenol.

To a small portion of the distillate add about one-fourth its volume of ammonium hydrate and then a small quantity of a solution of calcium hypochlorite. A blue color appears at once or on standing for a time in the presence of phenol.

To a portion of the distillate add bromine. If phenol be present a white precipitate of bromo-phenol is formed. This may be further tested, after it has been thoroughly washed, by treating it with sodium amalgam (prepared by dissolving sodium in mercury), and then making the solution acid. If phenol be present the characteristic odor of phenol will be developed. *Herbert M. Hill.*

CARBON DISULPHIDE.—CS_2. This body, commonly called by the older chemical title *bisulphide of carbon*, is official in the United States Pharmacopœia as *Carbonei Disulphidum*, Carbon Disulphide. It is thus described: "A clear, colorless, highly refractive liquid, very diffusive, having a strong, characteristic, but not fetid, odor, and a sharp, aromatic taste. Soluble in 535 parts of water at 15° C. (59° F.); very soluble in alcohol, ether, chloroform, fixed and volatile oils. Specific gravity, 1.268 to 1.269, at 15° C. (59° F.). Carbon disulphide vaporizes rapidly at the ordinary temperature, is highly inflammable, boils at 46°–47° C. (114.8°–116.6° F.), and, when ignited, burns with a blue flame, producing carbon and sulphur dioxide. It should not affect the color of blue litmus paper moistened with water" (U. S. P.). Carbon disulphide should be kept in tightly closed vessels and away from lights or fire. The "strong characteristic, but not fetid, odor" of the above description, though "not fetid" in a perfectly pure sample, is, in the article as commonly met with in the shops, of a rotten-egg quality, so disagreeable and so strong as to constitute a practical bar to a common medicinal use of the compound. The high volatility and extreme inflammability are also points of inconvenience, and the latter quality one of danger also.

Carbon disulphide is a powerful agent, of the general type of the volatile alcohols and ethers. It is locally irritant while yet specifically anæsthetic, and, absorbed into the blood, profoundly deranges the nervous functions in the same general manner as chloroform does. Habitually absorbed, as may occur by breathing the fumes in india-rubber factories, where the agent is largely used, carbon disulphide produces a peculiar form of chronic poisoning, elaborately described by Delpech as observed in Paris workshops. The poisoning commonly begins by severe headache, sometimes accompanied by an exhilarant intoxication. Later follow depression, mental apathy and dulness, loss of memory, impairment of sight, hearing, and sexual desire, and a very pronounced loss of muscular power. Cramps and various dysæsthesiæ are also common. The poisoning is seldom fatal, but, on the other hand, after full development, entire recovery of health and strength is unusual. Treatment is upon general principles, the only special agent recommended being phosphorus, by the use of which in small doses Delpech thinks he has abated the failure of muscular and virile power.

Medicinally the only properly allowable use of carbon disulphide is as a local application for the relief of surface pains. In this employment the action is like that of chloroform—conjointly anæsthetic and sharply irritant. An application of carbon disulphide causes for a few minutes severe pain, and may or may not be followed by subsidence of a neuralgia. The remedy may be used in vapor by saturating with carbon disulphide a sponge at the bottom of a wide-mouthed flask, and then pressing the mouth of the flask to the skin. Carbon disulphide has been given internally in doses of a few drops, but in the absence of any unique therapeutic powers such administration is certainly not to be recommended.

Edward Curtis.

CARBON, HYDRIDES AND OXIDES OF.—There are two well-known oxides of carbon, viz., carbon monoxide and carbon dioxide, or carbonic anhydride. They are both invisible gases at ordinary temperatures and pressures; and are of interest to the physician from the fact that they are both irrespirable gases with which persons are frequently brought in contact, and which frequently produce poisonous and even fatal results. Carbon dioxide plays an important rôle in the physiology of the human organism. The names used to designate these compounds are somewhat variable and confusing, and, to avoid this uncertainty, we place all the names commonly met with at the head of the proper sections.

CARBON DIOXIDE.—Also called *carbonic-acid gas* and *carbonic anhydride.* (Fixed air, choke damp.) Chemical formula, CO_2. Specific gravity (air = 1), 1.52; density (hydrogen = 1), 22.

Sources.—When carbon is burned in oxygen, or with a free supply of air, this gas is formed; hence it is a product of the combustion of all combustible bodies containing carbon. It is prepared in large quantities, by many manufacturing processes, from the combustion of coal. The burning of lime kilns sends large volumes of this gas into the air, partly from the fire and partly from decomposition of the limestone ($CaCO_3$) into lime and CO_2. Respiration is another source of the gas, and the expired air may accumulate in a tight room to such an extent as to become poisonous,—indeed, in some cases, to such an extent as to cause death. An adult man exhales about .7 cubic foot (20 litres) of CO_2 per hour, or 18 cubic feet (499 litres) per day. Another source of carbon dioxide is the alcoholic fermentation of saccharine fluids. This source is usually limited to certain kinds of industries, such as beer, wine, alcohol, and whiskey manufactories. In badly ventilated fermenting rooms, deaths have often occurred from the accumulation of this gas. The subterranean heat of volcanic regions causes the decomposition of limestone as above mentioned, giving off CO_2, which either escapes through crevices, or accumulates in underground caverns, under pressure, and finally becomes absorbed by the water, and comes to the surface in the form of effervescing spring-water, as at the well-known Saratoga Springs. The gradual oxidation of vegetable matters, either upon the surface of the soil or buried in it, generates a considerable quantity of carbon dioxide. The gas from these various sources may filter through the soil, crevices in the rock, or coal bed, and accumulate in mines, wells, cellars, etc., in such quantities that the miners are unable to work in it. It is called by them *choke damp,* to distinguish it from *fire damp.* It is produced in mines by an explosion of marsh gas (fire damp), so that if the explosion does not kill persons unfortunate enough to be in the mine at the time, they may die from breathing the CO_2 developed by the explosion. The atmosphere, as will be seen, is continually receiving this gas in abundance from the above sources; hence, outdoor air always contains about .4 part per 1,000. The air of rooms and closed places frequently contains a much larger proportion than this. A well-ventilated room should contain not more than .6 part per 1,000; but owing to poor ventilation it frequently rises as high as 4 parts per 1,000 or more. Even in the open air, the amount depends somewhat upon the state of the weather, season of the year, etc. In still, foggy weather in large cities, the amount present in outdoor air may rise as high as .8 part per 1,000, or enough to give the air a peculiarly suffocating effect upon those who breathe it.

Properties and Preparation.—Carbon dioxide is a colorless, transparent, odorless gas, about one and a half times heavier than air, and may be poured from one vessel into another like water. It has a faintly acid taste. At ordinary temperatures it is soluble in its own volume of water, with which it probably enters into combination to form carbonic acid: $CO_2 + H_2O = H_2CO_3$. By increasing the pressure, water will absorb a very large amount of the gas, a large portion of which escapes again when the pressure is removed. The so-called *plain soda* is a strong solution of carbonic acid (H_2CO_3) in water, made under pressure. The gas may be expelled by heat, by freezing, or by removing the pressure. Under a pressure of fifty atmospheres at 15° C. (59° F.), it is condensed to a transparent, colorless, mobile liquid, not miscible with water or fixed oils, but readily so with ether, alcohol, naphtha, turpentine, and carbon disulphide. When the pressure is removed from the liquid it evaporates with great rapidity, freezing a portion of the liquid into a snow-like solid, by the heat absorbed in the evaporation. The solid evaporates very slowly, and may be kept longer than the liquid. By moistening this solid with ether, and placing it under the bell-jar of an air pump, a temperature of −110° C. (−166° F.) may be obtained. Carbon dioxide is soluble in about one-third its own volume of alcohol at the ordinary temperature and pressure. Dry carbon dioxide has no effect upon litmus paper; but if the latter be first moistened it is reddened. On drying, the blue color is restored. Lime water is at first rendered turbid by CO_2, owing to the precipitation of calcium carbonate; but on conducting the gas into the turbid liquid for some minutes, the precipitate is redissolved, and the solution becomes clear again, owing to the formation of calcium bicarbonate ($H_2Ca(CO_3)_2$. This process frequently takes place in natural waters to produce *temporary hardness,* so called, because the calcium, and at times magnesium carbonate thus held in solution, is precipitated by boiling off the excess of carbon dioxide. Solutions of caustic soda, potash, lime, baryta, etc., rapidly absorb CO_2 with the formation of carbonates of the metals. Such solutions are used to dissolve the gas from mixtures containing it. The gas does not support either respiration or combustion, although this property is not peculiar to carbon dioxide. It is not combustible. Sodium, potassium, phosphorus, boron, carbon, iron, zinc, and magnesium, at high temperatures, decompose it by removing its oxygen and converting it into either carbon monoxide or carbon. It is also decomposed by the chlorophyl of plants under the influence of sunlight and moisture, the carbon combining directly with the water to form formaldehyde, $CO_2 + H_2O = CH_2O + O_2$, while the oxygen escapes in the free condition. The formaldehyde then readily polymerizes to form dextrose and the other soluble carbohydrates: $6\,CH_2O = C_6H_{12}O_6$. Carbon dioxide is usually prepared in the laboratory by treating a carbonate, usually calcium carbonate or marble, with a dilute mineral acid: $CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$.

Uses.—The following are among the most important uses of carbon dioxide: Notably, in the manufacture of carbonates and bicarbonates, carbonated beverages, white lead, the decomposition of sucrate of lime in the preparation of sugar from beets, in setting free the hypochlorites from chloride of lime, in bleaching, and in giving a *bead* to beer, ale, wine, etc.

Physiological Action.—The physiological effects of carbon dioxide vary with the degree of dilution or admixture with air. *When inhaled in the pure state* it causes almost instant death from spasm of the glottis and *apnœa.* Even when somewhat diluted, there is almost immediate insensibility and loss of muscular power, and the person drops as if felled by a blow, and usually dies without a struggle, unless immediately removed into pure air. Such accidents are most likely to occur from going into deep wells, caves, mines, etc., where the gas, termed *choke damp* by miners and well-diggers, has accumulated; or, from putting the head into a fermenting vat which has been closed for a time; or from venturing too near to the mouth of a lime kiln, burning buildings, or volcanoes.

When more largely diluted, or, as is most likely to occur, when the air is gradually poisoned by it, the first feeling is a sense of closeness; then follow weight or fulness in the head, pressure in the temples, giddiness, singing in the ears, somnolency, sometimes nausea and loss of muscular power. Death is preceded by coma, with stertorous breathing, rarely vomiting and convulsions; the face is usually of a leaden hue, or pale, and the heart's action, at first violent, finally stops. It is not poisonous when taken into the stomach.

Post-Mortem Appearances.—The body of a person killed by carbon dioxide usually presents a livid, or very pale, external appearance. The face has sometimes been found swollen and distorted, but usually it is placid and there is no evidence of a struggle. The body is found in an easy, natural position, as though in a sleep at the time of death. The superficial veins are usually prominent, and are filled with dark liquid blood. There is nearly always congestion of the brain and its membranes, with engorgement of the sinuses, and congestion of the lungs. The blood is usually liquid and dark-colored. When the source of the poisonous gas is from burning coals, the carbon dioxide is mixed with carbon monoxide, and the blood in this case is bright red instead of dark, and coagulates with difficulty. Putrefaction of the body after carbon-dioxide poisoning takes place slowly, and bodily heat and rigidity are retained an unusually long time. All the internal viscera are usually found congested.

Injurious (Non-Fatal) Effects of the Presence of Carbon Dioxide in the Air of Rooms.—Thus far we have discussed the action of carbon dioxide upon the economy when present in the air in sufficient quantity to cause death. When the air is not so largely charged with this gas, the symptoms and effects are less marked, but may still be sufficient to occasion some distress. When the air of a given room or locality contains more than 6 or 7 parts per 10,000, it is to be considered contaminated or impure. An adult man exhales about .7 cubic foot (19 litres) of carbon dioxide each hour. This quantity will raise the contents of 3,500 cubic feet of air from .4 to .6 part per 1,000 each hour. It is evident, therefore, that this amount of air must be supplied to each adult man each hour, in order to keep the air he breathes from having more than .6 part per 1,000, or so as not to add more than .2 part per 1,000. It has also been found that the air of a room cannot be changed more than three or four times per hour without causing draughts. Hence (3,500 ÷ 4 = 875) an adult man should have about 900 cubic feet of space for comfort, when proper care is had to ventilation. When air moves more than 19 inches per second a draught is perceived. If there were no ventilation through walls, which is rarely the case, an open window, having an opening of 6 square feet, would allow 3,420 cubic feet of air to pass, when the draught is barely perceptible; or enough for a healthy adult man. Parkes, in his "Hygiene," p. 161 (Wood's Library), gives the following figures as representing the average amounts of CO_2 given off per hour by persons of different ages when in a state of repose. For adult males (say 160 pounds), .7 cubic foot; for adult females (say 120 pounds), .6 cubic foot; for children (80 pounds), .4 cubic foot; for a mixed community, .6 cubic foot. Under these conditions the amount of fresh air to be supplied in health, during repose, ought to be: For adult males, 3,500 cubic feet; for adult females, 3,000 cubic feet; for children, 2,000; for a mixed community, 3,000 cubic feet, per head, per hour. As more CO_2 is evolved from the body on exertion, these figures are too low for workshops, factories, mines, etc. In mines it has been found that 6,000 cubic feet of air per hour is necessary to keep up the greatest energies of the men. With light work a man weighing 160 pounds throws off .95 cubic foot of CO_2 in one hour, while in heavy work the same man would throw off 1.96 cubic feet per hour. This would require for light work the delivery of 4,750 cubic feet of fresh air per hour, and for heavy work, 9,800 cubic feet. The amount of air necessary for cattle, horses, and other large animals, is estimated by Marcker ("Proceedings of Civil Engineers," vol. xii., pp. 298 and 308) as 1 to 1.5 cubic feet per hour for every pound of weight, or 1,000 to 1,500 cubic feet for every 1,000 pounds of weight. For small animals (sheep, dogs, cats, etc.), 150 to 180 cubic feet of air per hour should be supplied for each 100 pounds weight. Birds require even more. The following table, from Parkes' "Hygiene," shows the amount of contamination produced by one man in different-sized spaces for one hour and each succeeding hour:

TABLE TO SHOW THE DEGREE OF CONTAMINATION OF THE AIR BY RESPIRATION (IN TERMS OF CO_2), AND AMOUNT OF AIR NECESSARY TO DILUTE TO A GIVEN STANDARD OF .2 PER 1,000 VOLUMES, EXCLUSIVE OF THE AMOUNT ORIGINALLY PRESENT IN THE AIR.

Amount of cubic space (= breathing space) for one man in cubic feet.	Ratio per 1,000 of CO_2 from respiration at the end of one hour, if there has been no change of air.	Amount of air necessary to dilute to standard of .2 during the first hour.	Amount necessary to dilute to the given standard every hour after the first.
100	6.00	2,900	3,000
200	3.00	2,800	3,000
300	2.00	2,700	3,000
400	1.50	2,600	3,000
500	1.20	2,500	3,000
600	1.00	2,400	3,000
700	.86	2,300	3,000
800	.75	2,200	3,000
900	.67	2,100	3,000
1,000	.60	2,000	3,000

In hospital wards, where sick persons are confined, ventilation should supply more air than is required by the healthy. This is due not alone to the CO_2 which they give off, but to organic emanations which permeate the air and give it an unpleasant odor and closeness. In hospital wards, Parkes lays down the rule that the quantity of air supplied should be from 4,000 to 4,500 cubic feet per person each hour. The following table from Witthaus' "Chemistry" gives the amount of air which ought to be supplied to each person under the conditions annexed:

Situation.	Cubic metres.	Cubic feet.
Barracks (day-time)	35	1,236
Barracks (night-time)	70	2,472
Workshops (mechanical)	70	2,472
Schoolrooms	35	1,236
Hospital wards	85	3,004
Hospital wards (surgical)	170	6,004
Contagious and lying-in wards	170	6,004
Mines	150	5,297
Mines (coal)	170	6,004

This table assumes that no artificial light is used; but even in this case, the quantities given are smaller than most physicians would prefer to supply. No hospital ward occupied by a number of persons should supply less than 4,500 or 5,000 cubic feet of air, per person, every hour, and in the case of most septic diseases, outdoor air is to be preferred.

Carbon Dioxide from Gas-Lights.—A burner which burns 3 feet of gas per hour (ordinary size) produces about 2 cubic feet of CO_2 per hour, and removes a corresponding amount of oxygen from the air. It has been calculated that each burner of the usual form (not Argand) should be supplied with from 4,500 to 5,500 cubic feet of air per hour to prevent injurious contamination with CO_2. Owing, however, to the evolution of heat and watery vapor, and the removal of oxygen, a larger quantity than this should be supplied to keep the air comfortable. A cubic foot of coal gas produces about from .5 to .8 cubic foot of CO_2, being rather higher for "water gas" than for "coal gas." A burner consuming 3 feet of gas per hour would produce from 1.5 to 2.5 cubic feet of CO_2, being a little more than three adult men, or four average persons, would produce. Pettenkofer has determined that a burner consuming 5 feet of gas per hour, giving 12 candle power, gives off as much heat as 8 men, more CO_2 than 3 men, and as much watery vapor as 5 men. Adopting this as a basis of calculation, a 3-foot burner should be supplied with as much air as 3 persons, or about 9,000 feet per hour, to keep the air in a comfortable condition. In reality, this amount of ventilation is seldom obtained in a room of ordinary size. The basis of calculation that has usually been adopted is to furnish 1,800 cubic feet of air for each foot of gas burned. For the same illuminating power, oil does not give a greater degree of contamination than gas. An ordinary lamp gives about the same contamination to the air of a room as one adult man.

Tests for Carbon Dioxide.—The physician may be called upon to test the air of rooms, or enclosed spaces, for CO_2, either for diagnostic or for medico-legal purposes. The following simple tests may be employed: A moistened, blue litmus paper suspended in the air of the room is at first reddened and then bleached by carbon dioxide. If the amount of CO_2 exceed ten or twelve per cent., and if it have been added to the air, without the removal of any oxygen, a candle will usually be extinguished. If the CO_2 has been produced by combustion or respiration, the candle will be extinguished by five per cent. An atmosphere in which a candle will burn may be fatal to animals or man. Lime water or barium hydroxide (baryta water) is rapidly rendered turbid on pouring it from one vessel into another in an atmosphere rich in CO_2. A piece of filter paper dipped in lime water colored red with phenolphthalein is bleached white by CO_2, the rapidity of the bleaching depending upon the amount contained in the air. Or the same colored solution may be poured into a bottle filled with the air of the space as follows: Fill a quart bottle with water, and pour it out slowly in the room whose air is to be tested, or, better, siphon it out, using a piece of rubber tubing as a siphon. One cubic centimetre of thoroughly saturated lime water, colored pink with phenolphthalein, should be decolorized by 1.6 litre (1.6 quart) of outdoor air, or one quart (roughly) of ordinary indoor air. The air of a room should not decolorize more than 1 c.c. for each quart. The 1 c.c. (♏ xv.) of colored lime water may be diluted to 15 c.c. (℥ ss), with distilled water and poured into a quart bottle of the air, and shaken up. If the color be discharged, add .5 c.c., and so on until a permanent color remains after ten minutes' shaking. Where proper appliances are at hand, it will be much more accurate to use the following method:—

Pettenkofer's Method for Estimating CO_2 in Air.—A glass globe or bottle holding about 4 litres is carefully measured by filling it with water and then pouring the water out into a suitable graduated measure. The bottle is now filled by an air bellows with the air to be tested. Twenty-five cubic centimetres of barium hydroxide solution of known strength, in comparison with a $\frac{N}{100}$ oxalic-acid solution, are added, and the bottle is tightly corked and allowed to stand for a half-hour, with occasional shaking. At the end of this time the stopper is removed, a few drops of phenolphthalein solution added, and the $\frac{N}{100}$ oxalic acid run in from a burette until the pink color is just discharged. The oxalic acid combines with the unused BaO_2H_2, but does not decompose the barium carbonate formed by the CO_2 of the contained air. If the number of cubic centimetres of acid required to neutralize 25 c.c. of the barium hydroxide solution put into the bottle be known, or determined by a separate titration, the difference between this number and the number of cubic centimetres used in neutralizing the residual BaO_2H_2, will represent the acid equivalent of the CO_2 in the air contained in the bottle, expressed in cubic centimetres of $\frac{N}{100}$ acid.

If we make the oxalic-acid solution by dissolving .2863 gm. of the pure crystalline acid in a litre of water, each cubic centimetre will represent 1 mgm. of CO_2. The volume of 1 mgm. of CO_2 at 15° C. (59° F.) at the average air pressure, is .536 c.c. At 17° C. (62.6° F.) the volume is .544 c.c. At 20° C. (68° F.) it is .546 c.c. At 22° C. (71.6° F.) it is .549. By means of these figures the volume of the CO_2 found may easily be calculated by multiplying the number of cubic centimetres of acid corresponding to the loss of saturating power of the BaO_2H_2 solution, by the volume of 1 mgm. of CO_2 at the temperature of the room when the sample was taken. From the volume thus obtained it is easy to calculate the relation of this to the air taken. Suppose, for example, that the bottle contains 4,500 c.c. when full. After adding the 25 c.c. of barium hydroxide it would contain 4,475 c.c. Assume, also, that the temperature of the room at the time of filling the bottle is 22° C., or 71.6° F., and that the titration of the residual BaO_2H_2 in the bottle required 14 c.c. of the oxalic acid. Suppose, further, that 25 c.c. of the BaO_2H_2 solution requires 22 c.c. of the acid. Then $22 - 14 = 8$ c.c., the acid equivalent of the CO_2 in the contained air, and its weight = 8 mgm. At 22° C. the volume of 8 mgm. of CO_2 is $.549 \times 8 = 4.392$ c.c.

Then $4475 : 4.392 : : 1{,}000 : x = .986$ part of CO_2 in 1,000 parts of air.

CARBONIC ACID (H_2CO_3) exists only in solution. It has not yet been isolated. When an attempt is made to concentrate it, the acid breaks up into water and carbonic anhydride (CO_2), which escapes with effervescence. The salts of the acid, the carbonates and acid carbonates (bicarbonates) are well known. Carbonic acid is a feeble acid, and is expelled from its salts by most strong acids. The carbonates all effervesce when treated with the mineral acids, and this serves as a ready test. Some of the metals are dissolved by this acid, but with great slowness. Copper and lead are corroded by it, and hence these metals may contaminate "soda water," beer, etc., drawn through pipes composed of these metals.

CARBON MONOXIDE.—*Carbonous Oxide, Carbonic Oxide* (CO). This gas was discovered in 1799 by Priestley. It is always formed when carbon, or combustibles containing carbon, are burned with an insufficient supply of air. It does not occur free in nature except as the result of certain manufacturing processes. It is produced by the heating of coal with certain ores, such as those of iron and zinc. It is always prepared in an ordinary coal fire. The air entering through the grate produces at first CO_2, which, on coming in contact with the glowing coals above, is reduced to this lower oxide: $2CO_2 + C_2 = 4CO$.

This gas is the one which is frequently seen burning with a blue flickering flame at the surface of the coals in an open grate fire. The gas may be prepared for experimental purposes by passing carbon dioxide through an iron tube loosely filled with charcoal, heated to redness, or by heating in a flask a mixture of oxalic and suphuric acids. In the last method the gas is mixed with an equal volume of CO_2, which may be absorbed by passing it through wash bottles containing milk of lime.

Properties.—Carbon monoxide is a colorless, transparent, odorless, tasteless gas, which may be liquefied by a pressure of 35.5 atmospheres at −139° C. (−282° F.), or at ordinary pressures at a temperature of −190° C. (−374° F.).

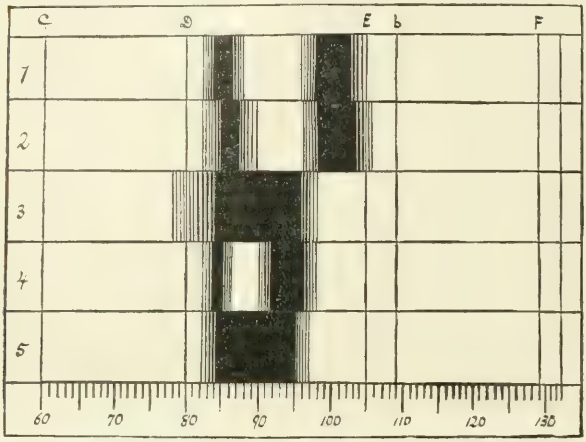

FIG. 1116.—1, Absorption bands of oxyhæmoglobin (Hoppe); 2, absorption bands of CO hæmoglobin, showing displacement of the bands (Hoppe). The same appearance is seen in the blood of persons poisoned by charcoal fumes or coal gas. 3, absorption band of reduced hæmoglobin, *i.e.*, it is No. 1, with a drop of ammonium sulphide added (Hoppe); 4 and 5, the same as Nos. 1 and 3, according to Hensen.

The density of the gas is 14 (H=1), and the specific gravity, .9678 (air =1), or nearly that of air.

It is but slightly soluble in water or alcohol. It dissolves in hot caustic potash (KOH) solutions, with the formation of potassium formate (KOCOH). It also unites directly with potassium, oxygen, and chlorine.

It dissolves readily in a solution of a cuprous salt in ammonium hydroxide; consequently, ammonio-cuprous chloride is used in the analysis of mixtures of gases to absorb the CO when present.

It burns readily in air, with a blue non-luminous flame, the sole product of the combustion being carbon dioxide. At high temperatures it has a very strong affinity for oxygen, and will take it from many of the metallic oxides. It is by its agency that iron ores are reduced to the metallic state in the blast furnace. The diffusive power of the gas is much greater than that of carbon dioxide, CO_2, and cast-iron plates, when red hot, allow it to diffuse through them with comparative ease. In this way a small quantity of the gas finds its way into the air of rooms heated by stoves, and especially by ordinary hot-air furnaces.

Sources.—The most frequent sources of carbon monoxide, likely to produce it in poisonous or dangerous quantities, are open charcoal or stove coal fires, defective stove pipes or furnace flues, and the escape of illuminating gas, especially the variety known as *water gas.*

A frequent cause of fatal poisoning by this gas is an open charcoal fire. This is sometimes used with suicidal intent, especially in some European countries. Leblanc gives the following analysis of the air of a confined space in which charcoal was burnt, and which proved rapidly fatal to a dog: Oxygen, 19.19 per cent.; nitrogen, 76.62 per cent.; carbon dioxide, 4.61 per cent.; carbon monoxide, .54 per cent.; marsh gas, .04 per cent.

In this case, however, the poisonous effects might not be due alone to the carbon monoxide, for 4.6 per cent. of carbon dioxide in an air containing 1.4 per cent. less oxygen than normal air would form a poisonous atmosphere.

Another source of carbon monoxide, and one which is frequently overlooked, is from escape of the gas through defective flues, or even through the red-hot walls of the flues or pipes of stoves and hot-air furnaces. The gas thus finding its way into rooms frequently gives rise to headache, dizziness, loss of appetite, nausea, debility, and bronchial irritation, which last effect is sometimes very severe. Indeed, severe cases of capillary bronchitis in children have been traced to an escape of poisonous gases from a defective flue. The ordinary hot-air furnace, in common use at the present day, is the cause of a considerable and undetermined amount of chronic poisoning, and is on this account open to very serious objection. From ordinary stoves, when the draught is rendered imperfect by the downward direction of the pipe before entering the chimney, carbon monoxide and other gases frequently escape into the room.

Perhaps the most frequent source of fatal quantities of this gas in the air, especially in large cities, is the escape of illuminating gas. From thoughtlessly blowing out the gas, or accidentally turning the stopcock, or having it turned by children, as occurred to a number of persons coming under the care of the writer, or from accidental leakage of pipes, the gas may find its way into a room in sufficient quantities to give fatal results. Even in waking hours, when the gas escapes slowly, the odor does not seem to be a perfect safeguard. (For a further discussion of this subject, see the section that treats of coal gas.)

Physiological Action.—Carbon monoxide is a very poisonous gas, entering the blood and combining with the hæmoglobin of the red corpuscles and expelling the oxygen. When the blood is pretty thoroughly saturated with this gas, death is usually, if not always, the result.

The blood of persons poisoned with this gas retains its bright cherry-red color for a long time after death, both in the body and out of it, and in the veins as well as in the arteries.

Properly diluted, the blood shows in the spectroscope two absorption bands situated between the lines *D* and *E*, but slightly nearer *E* than the similar bands of oxyhæmoglobin (see Fig. 1116).

These bands do not readily disappear when the blood is treated with ammonium sulphydrate, *i.e.*, the blood resists the action of reducing agents. In ordinary arterial blood, reducing agents change the spectrum, so that the two bands seen in 1 disappear, and one broad band, represented in 3, makes its appearance. Vogel has proposed to employ this peculiar behavior of hæmoglobin as a means of detecting CO in the air.

The process consists in shaking the mixture of gases with a drop of blood diluted with 2 or 3 c.c. of distilled water, and observing the spectrum of this blood solution. This method is said to detect 2.5 to 4 parts per 1,000, of this gas in the air.

Blood charged with carbon monoxide, in the absence of oxygen, resists the action of putrefaction for a long time. The CO may be expelled from blood by allowing any inert gas to bubble through it, or by placing it in a vacuum. The very poisonous character of CO is explained by the behavior of the hæmoglobin of the blood toward it.

Toxicology.—The poisonous action of carbon monoxide has been known since 1802, when Guyton Morveau first observed it. Leblanc and Dumas' experiments show that air containing 1 per cent. of the gas will kill a dog in one minute and a half. Dr. Letheby found that air containing .5 per cent. killed birds in three minutes. One per cent. of the gas in air renders it fatal to most animals, and .5 per cent. to some, even if the oxygen is normal or in excess of normal.

Symptoms of Acute CO Poisoning.—The symptoms of carbonic-oxide poisoning are singularly persistent. The first subjective symptoms are dizziness, excruciating headache, debility, and a feeling of prostration; nausea and vomiting are not uncommon; convulsions are frequently seen in experiments upon lower animals, as well as in human beings poisoned by it. This gas seems to act as a narcotic poison, death usually occurring by coma. The face is usually, though not always, livid, and the pupils are dilated. When the quantity of gas is not sufficient to produce such pronounced results as those above mentioned, and when this small quantity is breathed for days or weeks, the symptoms are those of malaise, debility, anæmia, anorexia, and usually headache. There is frequently a dry, irritative cough. These symptoms are sometimes mistaken for those of malaria, and probably are benefited by the tonic effect of quinine. When the severer symptoms are well marked, the chances of recovery decrease with the length of time the patient has been exposed to the gas. When the time of exposure has exceeded eight hours, and coma has set in, the prognosis is very unfavorable. If the time is less than eight hours, and the coma is not too profound, there is reason to hope for recovery. This statement is based upon experiments upon the lower animals, and the histories of a number of recorded cases. Much will depend upon the amount of gas breathed; but, other things being equal, the longer the blood is exposed to the gas, and the more thoroughly it becomes saturated with CO, the more permanent is the injury, and the less chance there is for recovery. The characteristic *post-mortem appearances* are: the bright red color and persistent fluidity of the blood, and hyperæmia of the brain and meninges. The heart is usually nearly empty and flaccid.

Chronic Poisoning.—The symptoms of chronic poisoning with carbon monoxide are somewhat different from those of acute poisoning. In this case the amount of gas is small and the time of exposure is long. The hæmoglobin absorbs the CO very slowly, while it also absorbs oxygen freely. Under these circumstances, a part of the CO-hæmoglobin is decomposed, but a part of it remains in the blood. The symptoms are generally vague, inconstant, and very often overlooked or attributed to other causes. The chief symptoms are malaise, anæmia, anorexia, and disorders of digestion. The person never feels well, but he seems better when in the open air. Indeed, fresh air and change of residence are the best and only treatment. The symptoms are such as to suggest chronic malarial infection. The origin of this form of poisoning is usually from leaking gas pipes either in the house or in the ground near the house, whence the gas reaches the dwelling by diffusion through the soil.

The *treatment* of cases of poisoning by CO are, briefly, fresh air, cold affusions, stimulants, and artificial respiration when demanded. Even with all these, death will result in those cases in which the exposure has been of long duration, and the coma pronounced, *i.e.*, when the blood has become well-nigh saturated with the gas. In such cases transfusion, or displacing the poisonous with pure blood, or even with normal salt solution, seems more likely to succeed. Good results have followed this method of treatment in a number of cases.

Illuminating Gas, Fuel Gas, or Coal Gas.—These names are applied to complex mixtures of gases, made from coal, wood, oils, resin, petroleum, shales, etc., by a process of destructive distillation. The most of these gases contain more or less of the oxides of carbon, especially of CO, and in this country they are the most frequent sources of poisoning by carbon monoxide. Much of what has been said as to the effects of this gas applies to illuminating gas.

Coal gas was first used for house lighting by William Murdock in London in 1792. It was first used for street lighting in London in 1812, and in Paris in 1815. In this country, especially in the larger cities and in some towns, the so-called *water gas* enriched with naphtha has nearly replaced coal gas. The complete apparatus for its preparation consists of: 1. A set of semi-cylindrical iron or clay retorts, set horizontally in a furnace. 2. A series of horizontal and upright iron pipes acting as condensers, in which the liquid products of the distillation are condensed and separated from each other, and from the gases. 3. One or more purifiers, which consist of upright stacks, containing moistened coke, freshly slaked lime, ferric hydrate, or mixtures of these with sawdust. The object of these purifiers is to absorb the most of the carbon dioxide, sulphuretted hydrogen, etc., before the gas is stored for use. 4. A gasometer or gas-holder, which consists of an inverted iron tub of large size floated in a well of water. The gas is conducted into this gasometer by a pipe leading from below and terminating above the water, where it is stored ready for use.

The coal is heated in the retorts to a cherry-red heat, or about 1,500° F. This temperature breaks it up into coke (which remains in the retort), liquid and volatile products, and gases. Ordinary bituminous coals yield about ten thousand cubic feet of rather poor gas per ton. It is a common practice to mix with these coals about five to ten per cent. of a rich boghead or cannel coal, to improve the illuminating power of the gas produced.

COMPOSITION.—The gas ordinarily used is a mechanical mixture of various gases, some of which are illuminating agents, while others have no value in this respect, but are combustibles furnishing considerable heat, while there are usually some present which are inert either as combustibles or as illuminants. Besides the true gases, there are present vapors of certain hydrocarbons, which are of value as illuminating agents. The chemical composition of the gas varies with the coal used, and the temperature to which it is subjected. The chief constituents of coal gas, with the quantities of each, are given in the following table from Letheby:

	Volume per cent.
1. Hydrogen	25 to 50
2. Marsh gas	35 to 52
3. Condensible hydrocarbons: Olefiant gas (C_2H_4), propylene (C_3H_8), butylene (C_4H_8)	3 to 20
4. Benzol and its series	(?)
5. Acetylene (C_2H_2	(?)
6. Naphthalene ($C_{10}H_8$)	(?)
7. Carbon dioxide (CO_2)	0 to 2
8. Carbon monoxide (CO)	5 to 9
9. Cyanogen (CNCN)	Traces.
10. Ammonia (NH_3)	0 to .06
11. Bisulphide of carbon (CS_2)	.004 to .05
12. Aqueous vapor (H_2O)	.6 to 2.5
13. Oxygen	0 to 10
14. Nitrogen	0 to 8
15. Sulphocyanogen	traces.

It will be seen that this table presents wide variations as to the percentage of the various gases. The illuminating power of the gas varies with the proportion of ethane, C_2H_6, ethylene (ethene), C_2H_4, acetylene, C_2H_2, and benzene, C_6H_6, and their homologues, and the heating value with the hydrogen, marsh gas, and carbon monoxide present. The specific gravity of coal gas is about from .400 to .650, air being taken as 1.

The illuminating power of gas is measured by comparison with a standard spermaceti candle of six to the pound, and consuming, as near as may be, one hundred and twenty grains of spermaceti per hour. It is assumed that the light given off is in direct proportion to the sperm consumed. The gas to be tested is to be burned at the rate of five feet per hour. Such a burner should give as much light as sixteen or eighteen standard candles. It may reach as high as twenty-five or thirty candle-power.

Water gas may be referred to here as a gas manufactured and sold for the same purposes as coal gas. Its manufacture is conducted on a large scale in most cities, and to a large extent it has taken the place of coal gas.

This gas is manufactured as follows: Steam from a boiler is forced through a bed of glowing anthracite coals, previously heated to a very high temperature by an air blast. The steam from the boiler is passed through pipes or flues over the fire box, so as to superheat it to a temperature of 800° to 900° F. In passing this hot steam through the coals the water is decomposed, the oxygen combines with the carbon of the coal to form carbon dioxide, which is reduced, by the heated coal above, to the monoxide: $C + 2H_2O = CO_2 + 2H_2$. ($CO_2 + C = 2CO$). The hydrogen of the steam remains in a free state. After the steam has passed through the coal for about six minutes, the latter cools off and the process stops. The air blast is now turned on until the coal is again heated to the required degree—*i.e.*, for about eight minutes—when the steam is again passed into it. It is, therefore, an alternating process. The gas thus produced has very little illuminating power, but answers well for heating purposes. To give illuminating power it must be charged with hydrocarbons. This is accomplished as follows: Naphtha, or light benzin, is placed upon shelves in a carburetter, and the gas passed through the apparatus. A small quantity of the vapor of the naphtha is taken up by the gas. This mixture is now passed through retorts heated to bright redness, by which process the vapors are decomposed and converted into permanent gases instead of condensible vapors. This is the Tessie-du-Motay process. By the Lowe process the carburetted gas is made in one operation instead of in two, as above described. Water gas is cheaper and usually of higher illuminating power than coal gas, and is consequently superseding the latter.

The principal differences in the chemical composition of coal gas and water gas are, that the latter, as usually manufactured, contains a larger percentage of illuminating agents and of carbon monoxide than the former.

The following analyses of the two gases, by Professor Remsen and Dr. Love, will serve to illustrate these differences:

Constituents.	Remsen.		Love.
	Coal gas.	Water gas.	Water gas.
Carbon dioxide	0.0	0.3	0.0
Illuminants (ethylene, propylene, butylene, ethane, propane, butane)	4.3	12.85	15.75
Carbon monoxide	7.9	28.25	21.51
Hydrogen	50.2	30.30	46.49
Marsh gas (methane)	29.8	21.45	11.75
Nitrogen	7.8	6.85	4.30
Oxygen	....	....	.20

Oil gas is now largely made by heating petroleum, tar, or shale oils in a retort to a temperature of about 1,000° C. This gas, especially that made by the Pintsch process, is much used in lighting cars. Oil gas is frequently used to enrich other gases of low illuminating power.

Air gas, so called, is produced by passing air through layers of very light petroleum distillates, known as gasolene, when it takes up enough of the light hydrocarbons to form a combustible mixture. Air gas is much used where other gas is not available. It cannot be stored long or piped a long distance because of the condensation of the illuminants.

Acetylene, C_2H_2, has recently become prominent, and is used as an illuminant in small lamps. It is prepared by treating calcium carbide with water, when the following reaction takes place:

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2.$$

The calcium carbide is prepared by heating a mixture of powdered coke and lime in an electrical furnace. One ton of calcium carbide of eighty-per-cent. purity is said to produce 1,000 cubic feet of acetylene gas. Its illuminating power is very high, and when burned in an ordinary burner gives off considerable soot. When burned in a specially constructed burner it gives a light of great brilliancy. The cost of production prevents its general adoption for illuminating purposes. Acetylene combines with copper and silver, forming acetylids, which are explosive. It combines with the hæmoglobin of the blood, and thus acts as a poison. The gas has a pungent, suffocating, disagreeable odor, by which its presence in the air can usually be detected.

Fuel Gas and Furnace Gases.—Gases of more or less poisonous character are produced during various smelting and roasting processes and which may be the cause of serious accidental poisoning. The most commonly met with are arsine (arseniuretted hydrogen), stibine (antimoniuretted hydrogen), and sulphurous oxide, obtained by roasting ores containing arsenic, antimony, or sulphur, and CO_2 and CO obtained in smelting processes generally.

Carbon monoxide is an important constituent of *fuel gas* or *producer gas*. Producer gas is made by forcing air through a bed of incandescent coal or coke in specially constructed furnaces. It contains from twenty-five to thirty per cent. of CO, to which it owes its value as a fuel. It also contains some CO_2 and free nitrogen. In another form of furnace steam is forced through the heated coal, when CO and hydrogen are produced, as in making *water gas*. It is needless to say that both these gases are poisonous.

Natural gas is so called because it exists already formed in the earth whence it issues spontaneously, or is obtained by boring wells. The gas is found chiefly in localities where petroleum is found. In this country this gas is found in western Pennsylvania, in eastern Ohio, in West Virginia, and in Fredonia, N. Y. At the last-named place it was used as an illuminating gas as early as 1821.

The "Burning Springs" of Baku, on the Caspian Sea, have been known since the sixth century B.C. The composition of natural gas is fairly uniform, and it consists of about ninety per cent. of marsh gas (methane) with small quantities of ethane, C_2H_6, propane, C_3H_8, and other paraffin hydrocarbons, hydrogen, carbon monoxide, and carbon dioxide.

It is a valuable fuel, burning with a feebly luminous flame, but giving out an intense heat. In many localities it is the chief fuel. When heated in a suitable furnace with petroleum or the higher hydrocarbons, its illuminating power may be greatly increased and it is then used for illuminating purposes.

Action of Illuminating Gases on the Economy.—All forms of illuminating gas are irrespirable and more or less poisonous.

They are irrespirable because they do not furnish oxygen. The chief poisonous agents are carbon monoxide and the heavier hydrocarbons mentioned above under the name of *illuminants*.

The physiological action of carbon monoxide has already been discussed in the section which treats of that subject.

The heavy hydrocarbons are more or less poisonous when mixed with air. The symptoms produced are dizziness, headache, nausea, and prostration. These compounds are more deleterious than is the lighter marsh gas, but their exact physiological action is not well understood. The physiological effects of illuminating gas are due not alone to the carbon monoxide, as some have supposed, but to the combined effect of this gas and the heavier hydrocarbons, together with the loss of oxygen due to the displacement of air by the gas.

Symptoms.—The symptoms of acute poisoning by ordinary illuminating gas are: headache, dizziness, nausea, a staggering gait, great muscular weakness, prostration, loss of memory, and finally, unconsciousness and complete asphyxia. Convulsions frequently end the scene. There is usually little difficulty in making the diagnosis, as the circumstances under which the patient is found, the odor of the gas, etc., will prevent deception. The only diseases likely to be confounded with this form of poisoning are, cerebral apoplexy and uræmic coma. Should the physician not see the patient before the odor of the gas has escaped, such difficulty might arise. In both of these diseases the symptoms are pretty constant, while in *coal-gas* or *water-gas poisoning* they are apt to fluctuate; the patient will frequently rouse up for a time, and answer questions intelligently, and then lapse into unconsciousness, or be seized with convulsions.

A marked difference in the symptoms will be noted, dependent upon whether the gas is admitted into the air rapidly or slowly. In the first condition the person rapidly becomes unconscious, and recovers rapidly when removed into fresh air. When the gas is admitted to the air of a room slowly, the headache, dizziness, nausea, and muscular weakness are the prominent symptoms, and they are remarkably persistent. The condition of the patient often seems to remain constant for days after the accident; and when entire unconsciousness has occurred, recovery is very unusual. We should distinguish between asphyxia by illuminating gas and poisoning by carbon monoxide obtained by breathing the diluted gas. The first is produced by a rapid displacement of the air of the room with the gas, while the second results from a slower and very gradual admixture of gas with the air.

Fresh air and stimulation will usually suffice to restore the patient in the first case; but in the second, while these measures should not be neglected, they are much less useful, and, when the time of exposure has been considerable, of slight benefit. It may be well to name here some of the sources of coal-gas poisoning other than leakages directly from fixtures in the room.

The odor of the gas is so characteristic that this will in most cases give its warning. Repeated instances, however, prove that people may be killed by this gas without detecting the odor.

Cases of poisoning have occurred when the leak in the pipes occurred in an adjoining room, or in a cellar or other room underneath. Most of such accidents occur in the night while the victims are asleep, even though they were exposed to the same influences during the preceding day.

It should be known that these poisonous gases may diffuse themselves through walls, soil, and partitions. It should also be remembered that the odorous vapors may be almost entirely removed by diffusion through a thick wall or several feet of soil. The gas deprived of its odor may thus pervade the air of a sleeping- or sitting-room, and give no warning of its presence.

In winter, when the ground is frozen, and the upper layers are impervious to the gas, this may diffuse itself several feet laterally from a broken street main, reach the cellar, pass thence to the rooms above, and so do its deadly work unperceived. That this accident has frequently occurred is shown by abundant evidence taken from the statistics of any large city. Aside from the fatal cases of poisoning from this source, we can easily see that there must be a much larger number of cases in which headache, dizziness, loss of appetite, general debility, anæmia, etc., may be dependent upon a smaller amount of the same gas continually finding its way into the air of houses.

It is evident, from the above, that cases of poisoning may occur in houses where gas is not used, and where the pipes do not even enter the house.

There has been, at various times, not a little discussion as to the relative poisonous effects of coal gas and water gas. This question has been made the subject of a great number of investigations. We may note that of Commissioner Raymond, of Brooklyn, N. Y., Health Department, 1883, and that of the Committee on Manufactures of the Massachusetts Legislature of 1884.

The weight of experimental evidence, however, goes to show that *water gas* is decidedly more dangerous than *coal gas*.

With a given amount of gas, the danger line is reached sooner with water gas; and, indeed, in many rooms it is not easy to get a fatal mixture of *coal gas* and air with the escape from a single burner jet, owing to natural ventilation through walls, floors, windows, etc. That is, dogs, cats, rabbits, and pigeons will endure almost indefinitely an atmosphere containing one per cent. of coal gas, while the same animals die in from five to eight hours when exposed to an atmosphere containing one per cent. of water gas.

The post mortem appearances, in cases of poisoning by illuminating gas, are similar to those found after poisoning with carbon monoxide. There is generally an odor of the gas about the body, especially on compressing the chest, so as to expel the residual gas from the lungs.

The countenance may be pallid, pink, or purple, varying in different cases. Frequently more or less froth will be found issuing from the mouth, due probably to the nausea which precedes death, and which is one of the marked symptoms. Occasionally, rose-colored patches will be found on the thighs or other parts of the body.

When the body is opened the blood will generally be found everywhere in a fluid condition, and uniformly of a light red color on both sides of the heart. It shows the spectroscopic bands of carbon-monoxide hæmoglobin see Fig. 1116, p. 662). The lungs will usually have a brilliant red hue, while the bronchial tubes will be filled with a frothy mucus. The venous sinuses of the brain and the vertebral nervous system will be found engorged with blood.

The above appearances are not always found, however, for there is great variation in this form of poisoning, both as to the symptoms and as to the post-mortem appearances. These variations are probably explained by the fact that in some instances the cause of death is a true asphyxia, while in others it is CO poisoning. In the former we may expect a livid hue of skin, dark, clotted blood, and engorgement of the venous sinuses; while in the latter we may expect the light, fluid blood, the rose-colored spots upon the skin, a lingering death, etc. More careful observation is needed upon these points.

Treatment.—We have incidentally mentioned nearly all that can be said of the treatment of coal-gas poisoning. If the case is one of suffocation, and the time of exposure has not been too long, fresh air, stimulants, and rest will usually suffice to restore the patient to consciousness.

No antidote for poisoning by the gas is known. Transfusion of blood has been tried with apparent success.

In experiments upon the lower animals the introduction of normal salt solution into the veins has occasionally been successful in saving life.

Inhalations of oxygen have often been tried, with temporary benefit, but it does not seem to expel the carbon monoxide from the blood. If persisted in, it may save life when the blood is not too nearly saturated with the gas. *Elias H. Bartley.*

CARBON TETRACHLORIDE.—*Tetrachloromethane, Chloro-carbon:* CCl_4. This body is a colorless, thin, ethereal fluid, of a pleasant aromatic smell, insoluble in water but miscible freely with alcohol and ether. It has been tried as an anæsthetic and has been found to operate after the general manner of chloroform, but with such a depressing effect upon heart action that it is little likely ever to come into practical use. *Edward Curtis.*

CARBONIC-ACID WATER.—"*Soda water.*" Carbonic-acid water is the product of the solution of carbon dioxide (carbonic-acid gas) in water. In such solution there is a chemical union between the gas and the water, molecule for molecule, producing the body *carbonic acid* proper

(H_2CO_3), which is known only in solution. At the ordinary pressure of the atmosphere water dissolves about one volume of carbon dioxide, but will take up increased quantities under artificial increase of pressure in direct proportion to the pressure. The carbonic-acid water of commerce contains from five to ten volumes of gas forced to dissolve by pressures varying from five to ten atmospheres. Such supercharged solutions appear as colorless aqueous fluids, effervescing briskly on release from confinement, from spontaneous evolution of the excess of carbon dioxide. The reaction is acid and the taste pleasantly acidulous and pungent. For obvious reasons commercial carbonic-acid water must be kept strongly confined in well-stoppered vessels, and special care is necessary that there be no exposed surface of lead or copper in the storing vessel, else contamination of the water with those metals will result. A carbonic-acid water charged with five volumes of gas was formerly official in the United States Pharmacopœia, but was dismissed in the revision of 1880.

Carbonic-acid water is valuable medicinally as a drink, and as a vehicle for medicines. As a drink its virtues are that, like all acids, it tends to excite the secretion of saliva and buccal mucus, and so relieve thirst more permanently than plain water, and that it is peculiarly grateful to the stomach, tending to expel flatus and allay nausea. As a vehicle for medicines, carbonic-acid water is especially adapted for the solution of mawkish salts, such as the purgative salts and alkaline carbonates, bromides, and iodides. Not only is disagreeable taste thus disguised, but the salt, whatever it be, is much less liable to disorder the stomach.

It is almost needless to say that all effervescing drinks —mineral waters and sparkling wines or malt liquors—owe their effervescence to carbonic acid formed by the solution in the liquid of carbon dioxide under pressure.

Edward Curtis.

CARBO-SAPOL is a mixture of 50 parts of carbolic acid, 25 parts of yellow soda soap, and 25 parts of potash or soft soap. These substances are heated together on a water bath until they form a clear solution. Carbo-sapol is miscible with water in all proportions, and has a strong antiseptic action. The combination of soap with carbolic acid makes it decidedly useful for cleansing the skin before an operation, or for soaking the hands. A one-per-cent. solution may replace creolin or lysol as a vaginal or intra-uterine douche. It may be used for instruments in one- to five-per-cent. solution, and these must be rinsed off before they are employed, as the soapy solution makes them slippery.

W. A. Bastedo.

CARBUNCLE.—*Carbunculus simplex seu benignus.* (See also *Anthrax* and *Boils* in this Handbook.)

[Some eminent authorities consider simple carbuncle to be a form of anthrax (*Anthrax furonculeux*), and apply this designation to the local lesion. This seems calculated to create confusion, as the nature and course of the two diseases are widely different; and the essential element of malignant pustule—the bacillus anthracis—is not found in the fluids or tissue in cases of simple non-malignant carbuncle.]

Carbuncle is an inflammation of the skin and connective (cellular) tissue of a greater or less degree of severity, accompanied by the loss of a certain amount of tissue, and exhibiting a tendency to mortification of the skin.

Carbuncle commences in the subcutaneous structures and works its way through the planes of connective tissue, as well as toward the surface. A brawny inflammation around an acutely inflamed central tumor is formed, with multiple points of suppuration, with a strong tendency to lateral extension. It is this latter tendency, and the consequent much larger size of the carbuncle, and the multiplicity of the points of suppuration which distinguish the carbuncle from the boil. Carbuncles are chiefly situated on the nape of the neck, and on the back or buttock, but they may also occur on the extensor surface of the forearm, and on the scalp or face, or in other locations.

The symptoms belonging to carbuncle are of a much graver character than those attending furuncle (see under heading *Boils*), and are accompanied by more or less significant signs of constitutional disease, such as fever, headache, anorexia, etc. The formation of a carbuncle is always preceded by more or less serious impairment of the general health, by a feeling of malaise, and sometimes by successive chills. These symptoms become intensified until the local disease is manifested by elevation of temperature, and by redness and swelling of the part, accompanied by a feeling of deep, and at times ill-defined, induration.

Etiology.—Carbuncle is now generally believed to be caused by the infection of the site of the disease by means of a bacterial germ, which gains admission to the subcutaneous tissues through some wound of the skin, such as a minute scratch, a slight abrasion, or possibly by finding its way downward through the follicle of a cutaneous hair, without previous injury of the skin. The organisms most frequently found in the pus of a carbuncle are the Staphylococcus pyogenes aureus and albus (Warren). A state of general debility places the tissues in a condition to furnish a favorable soil for the growth of the bacteria. Certain constitutional diseases, such as diabetes, are frequently accompanied by carbuncle. Carbuncle is rarely observed in childhood. It is most frequently seen in persons over forty years of age. It first appears as a minute papule on the surface of the skin, which is usually the seat of considerable irritation, and sometimes of acute pain. From this point the area of commencing inflammation gradually enlarges, extending laterally, and involving also the deeper tissues of the part, until a cone-shaped area of the tissues is involved in the process. Warren explains the peculiarities of carbuncular inflammation by reference to the anatomy of the skin in the regions most frequently the seat of the disease. He says (*op. cit.*): "The skin in this region is extremely thick (neck, back, etc.), probably thicker than in any portion of the body; it forms a mass of dense fibrous tissue, well calculated to sustain burdens, or to protect a comparatively defenceless portion of the body. The hair follicles being those supporting downy hair only, and therefore shallow, project downward only a short distance into the uppermost layers of the subcutaneous tissues. Communication with the adipose tissue is by oblique columns of fatty tissue which extend upward from below. These fat columns [first described by Warren] are found beneath each hair follicle. They contain besides loose connective tissue, fat cells and vessels, and a coil of sweat gland suspended midway in the shaft. At the point where these columns open into the parts immediately below this dense sheet of cutis is found a broad band of fibrous tissue, given off from one side and extending obliquely down into the subcutaneous structures, finally to be attached to the fascia, beneath which lie the muscles. These fibrous bands which interlace in various directions, are very different from the delicate cellular tissue underlying other portions of the skin, and form a dense network which holds firmly in place the tough hide to which they are attached." When further developed, the carbuncle presents a broad, flattened surface of round or oval outline, elevated to a greater or less degree above the surface of the surrounding skin, which is of a bright or dull red, or sometimes of a tawny color, and which is very tender to the touch. The skin is tense and hard, and the density of the surrounding tissues is greater than in ordinary inflammations of these structures.

Course of the Disease.—When the inflammation has involved an area of a certain diameter, its periphery becomes fixed, and it rarely afterward progresses beyond this boundary. Soon a slight elevation of the epidermis is noticeable, which speedily ruptures and gives exit to a clear gelatinous or sero-purulent discharge, which quickly dries and forms crusts about the orifice of exit. This is not accompanied by amelioration of the pain, redness, heat, or swelling, nor does it in the least check the progress of the disease.

As the carbuncle increases in size, the distress, which at first is usually not excessive, becomes gradually more intense, until it reaches a stage when it can be compared to nothing but a violent burning pain located deep in the tissues, and accompanied by throbbing and often by agonizing exacerbations, owing to the fact that the skin is held down firmly to the fascia by the fibrous bands already described. The dense cutis vera also does not yield to the pressure from below; the disease therefore advances from one columnar interspace to another and thus gradually implicates the deeper tissues. The pus makes its way to the surface through the points of least resistance, these points being the columnæ adiposæ, and thus the carbuncle becomes the seat of numerous small openings scattered irregularly over its surface, which lead down to the seat of the disease in the deeper tissues of the part. After a time the centre of the carbuncle usually becomes gangrenous.

The infiltration and disintegration of the tissues and the overlying skin are often so complete, and coagulation necrosis is so extensive, that large sloughs are formed. The centre of the carbuncle thus becomes an open crater. This may be confined to a small portion of tissue, and does not always lead to any considerable destruction in the part; but it usually occasions a loss of substance to a greater or less amount, sometimes reaching an area of 25 to 30 cm. in diameter. This stage is often accompanied by a notable relief from the pain.

Irregular fragments of necrosed connective tissue or aponeurosis are often separated during the process of healing, and appear at the orifices upon the summit of the carbuncle, where they are discharged spontaneously, or may be extracted by operative measures. When the necrosed tissues are retained beneath the skin, they frequently give rise to abscesses in the periphery of the original seat of disease, and thus increase the severity of the local lesion and augment the danger to the patient, as well as enlarge the surface to be subsequently healed. The change of the livid color at the border of the induration to a yellowish hue is an indication that the disease has reached its limit in extent.

When the gangrenous tissue which forms the centre of the carbuncle has been entirely eliminated, the process of repair commences, by the gradual formation of a cicatrix over the seat of the disease. This is generally a slow process, and in some cases is not completed on account of exhaustion of the healing power of the system.

In the milder cases there may be little or no fever; but large carbuncles are usually associated with considerable cachexia, and the condition of the patient at times becomes critical.

The duration of the disease varies according to the age and condition of the patient, and the means employed in its treatment. If the carbuncle is early and thoroughly incised, a complete cure may sometimes be attained in from one to three weeks, although cases often require six months for healing. The average duration of the disease is considered by competent authorities to be from one to two months.

Diagnosis.—In its early stages it may be impossible to differentiate carbuncle from the ordinary furuncle; but the diagnosis would soon be rendered positive by the course of the disease. The furuncle is quite superficial, affects only a limited amount of tissue, may be located upon any part of the body, is not accompanied by grave constitutional symptoms, is developed quickly, is not limited to any particular period of life, and is relieved by spontaneous opening or by surgical incision. The carbuncle, on the contrary, is situated in the deeper tissues, especially in parts like the neck, back, scalp, etc., in which are broad aponeurotic expansions. It usually occurs in patients already the subjects of diminished vitality from other causes, and should excite suspicion of diabetes, alcoholism, or marked uric-acid diathesis. Carbuncle is accompanied by grave and often alarming constitutional symptoms, by high fever, and by extreme restlessness; it is the seat of great and continuous pain, which is not relieved by the formation of an opening. The inflammation extends a considerable distance beneath the surrounding tissues, and is sometimes followed by extensive gangrene of the superficial structures or by phlegmonous inflammation of the adjacent parts, and is, *par excellence*, a disease of advanced life.

The simple non-specific carbuncle may properly be regarded as a group of deep-seated furuncles, situated beneath a dense and resisting cutaneous surface, which undermine and cause necrosis of a relatively large amount of tissue, with subsequent gangrene of the overlying skin, sometimes to a very alarming extent. The simple furuncle has a tendency to heal as soon as an opening occurs; the carbuncle shows no such tendency.

Carbuncle may be confounded with commencing erysipelas, and with a simple phlegmon of the subcutaneous connective tissue; but these diseases lack the localized character, the surrounding induration, the punctated surface, and the extensive sloughing of a circumscribed portion of connective tissue. Phlegmon is more boggy and diffused than is commencing carbuncle, the pain and fever are not so marked or constant, and the course of the symptoms is more rapid. Erysipelas is accompanied by intense febrile reaction, a more diffused swelling of the skin, vivid redness, and a clearly marked boundary of the disease, with lines of inflammation over the lymphatic channels and infiltration of the lymphatic glands. There is usually no tendency on the part of a carbuncle to extend beyond its original limit.

Carbuncle often presents a striking similarity to anthrax (malignant pustule), and might sometimes be mistaken for this malady, during its early stages, at the time when a small phlyctenular elevation of the epidermis upon an indurated and swollen base is the only visible variation from the normal condition. But carbuncle is rarely accompanied by the glandular enlargement, by the peripheral or extended œdema, or by so profound signs of constitutional disturbance as is the more grave disease. Aside from these points in diagnosis is the important fact that malignant pustule is observed chiefly, if not exclusively, among those who have been in some way brought in contact with some substance containing the infection, and therefore is more especially confined to those persons who are obliged to handle the flesh, hair, wool, skins, etc., of animals, or to those who are engaged in the care of animals already diseased, as grooms and shepherds (in the grazing regions of North America the disease might be expected among cowboys). The dried hides of animals, particularly those received from South America, frequently contain the virus of malignant pustule, and constitute a source of infection to curriers, tanners, and others employed in their manufacture; and in persons following these occupations any form of boil or carbuncle should be regarded with suspicion until anthrax can be excluded.

The more frequent seat of carbuncle is the neck and back; then the scalp, thorax, face, and limbs. Cases have been reported in which the eyelid and the lip were the seat of carbuncle, but these must be exceedingly rare.

Pathology.—Carbuncle may be regarded as the manifestation of a septic invasion of the affected tissues with subsequent coagulation necrosis and gangrene of the infected structures, accompanied if not preceded by a depraved condition of the general system. It has been noticed that other signs of a constitutional affection are often present in carbuncle. Thus Prout observed, in 1840, that the outbreak of the local disease was frequently accompanied by the urinary symptoms of diabetes; though it is quite possible that the diabetic phenomena and the carbuncle may belong to the outward manifestations of some grave constitutional affection, possibly of some department of the nervous system. The local features of carbuncle are essentially those of a septic infection, and are to be regarded as such so far as prognosis and treatment are concerned.

Prognosis.—In speaking of the lesion of carbuncle, allusion was made to the ordinary furuncle as the mildest form of this affection. In prognosis the same relation holds true. The furuncle is superficial in location, runs its course without fever, and is uniformly followed by rapid recovery, leaving a small cicatrix, which is usually but slightly depressed below the level of the surrounding skin. The prognosis of carbuncle, however, depends upon three factors, viz.: the age and vigor of the patient; the gravity of the constitutional symptoms, the amount of pain, etc., and the degree of interference with the process of alimentation; and the situation and extent of the local disease and the degree to which gangrene of the skin or sloughing of the deeper tissues occurs.

Death may occur from exhaustion, or from the development of secondary abscesses in the vicinity of the original carbuncle, especially if these take a phlegmonous course. A fatal issue also results in some cases from profound depression of the vital powers, apparently due to the absorption of the toxic poison of the disease. Hemorrhage and embolism have also been the cause of death in carbuncle. When the disease is situated on the neck or scalp, septic meningitis has not infrequently been a fatal complication.

When the carbuncle is situated upon the neck it may produce dyspnœa by pressure upon the air passages; when it is located upon the chest or abdomen the pleura or peritoneum may become inflamed; when upon the face, distortion of the features may ensue; and when situated upon the scalp it may be followed by meningitis.

Treatment.—Carbuncle is believed to arise from an infection of the skin and subjacent tissues by a definite bacillary organism, and is accompanied by a depraved condition of the general health; and therefore the first indication would be to restore as far as possible the normal vigor of the system and to bring about a better nutrition of the body. Some of the most celebrated authorities recommend the employment of active emetics, followed by cathartics, for the purpose of increasing the eliminative function of the digestive canal, and possibly, also, as a means of derivative action upon the seat of the disease by assisting in the removal of the toxins produced by the bacillus. When we consider, however, that the patient with carbuncle is generally already in a state of impaired vigor, any active depletory measures should either be entirely abstained from or should be adopted with great caution, lest they induce a dangerous degree of exhaustion or be followed by sudden collapse.

A careful regulation of the food, in regard both to quality and to quantity, is generally necessary, and at the same time active tonics and stimulants must be administered. The distress is frequently so great as to require the use of anodynes, and often the degree of febrile reaction is an indication for the employment of large doses of quinine. Cod-liver oil has also been found useful. If rapid exhaustion supervenes, the administration of champagne has sometimes been followed by great benefit. When convalescence is established, iron should be given, a generous and strengthening diet should be ordered, and, if possible, sea bathing or a change of climate and surroundings should be advised.

Locally, the treatment must depend much upon the symptoms belonging to each particular case. At times the application of cold is of great service in relieving the pain and modifying the severity of the inflammation, but generally hot and moist applications are most comfortable to the patient. These may consist of simple hot compresses, but the most common mode of treatment is by means of large poultices which should be frequently changed. At times the local abstraction of blood by means of leeches affords temporary relief, but the bleeding is liable to be excessive in amount, and may induce a condition of collapse.

The surgical treatment of carbuncle should have for its object the liberation of the sloughing tissue in the centre of the carbuncle, and the free exposure of all suppurating parts. For this purpose many methods of procedure have been advised, such as the circular incision around the base of the carbuncle; the cauterization of the summit of the swelling by means of potash or ferrum candens; the crucial incision of the entire carbuncle, the subcutaneous stellar incision through its substance; and the treatment by compression of the entire carbuncle; or of its peripheral portions, by means of firm or elastic bandages.

All operative measures should be carried out with the strictest attention to antiseptic precautions. The seat of the disease should be previously rendered as nearly aseptic as possible.

The treatment by circular incision consists in cutting a channel quite around the base of the carbuncle, so as to divide the skin and the superficial blood-vessels, and has for its object the diminution of the vascular supply, with the result of relieving the tension and reducing the febrile action in the part, and thus modifying the severity of the process and hastening the recovery. It is more especially to be employed in the early stages of the disease before gangrene has occurred, and while the central slough may yet be quite small.

The application of caustic potash or the hot iron to the summit of the carbuncle has the aim to provide a path for the release of the sloughing centre of the diseased part, and at the same time to avoid the unnecessary loss of blood from hemorrhage. The tissue to which the cautery is applied is destroyed without bleeding, and the interior of the carbuncle is rendered accessible to direct treatment. This mode of treatment is not often employed, as it is painful in its action and the resulting benefit is not greater than that from other and less distressing methods. During the last few years the antiseptic treatment has superseded all other forms. In cases of great debility or in aged patients, as well as in mild forms of carbuncle, the use of carbolic acid in dilute solution, either as a lotion or on compresses as a poultice, is of service.

The crucial incision of the entire carbuncle from base to summit is doubtless the most useful and effectual manner of exposing the interior of the swelling to view, and of liberating the sloughing centre in the most rapid manner. When the operation is completed the carbuncle presents four deep incisions radiating from the centre to the periphery. By this means the whole interior of the diseased part is made accessible to direct treatment and the most favorable conditions for rapid and complete recovery are at once established. The incision of the skin over the inflamed part, however, may be attended with a considerable loss of blood, which in the debilitated condition of many of the subjects of this disease is of no small importance. To obviate this, and thus to save the strength of the patient, the method of subcutaneous stellar incision has been adopted in many cases of extensive carbuncle.

This mode of treatment consists in the internal division of the seat of disease into many small sections, and has for its object the rapid and easy evacuation of the sloughing tissues of the centre of the carbuncle and the liberation of purulent matter, with the avoidance of excessive hemorrhage.

In performing this operation the surgeon makes use of a long and narrow knife, which is inserted into the perforated centre of the carbuncle and carried directly to the bottom of the disease. Its point is then directed outward toward the periphery of the carbuncle, and when the external boundary has been reached the edge of the knife is turned toward the skin, and the tissue is carefully cut from below toward the surface. The incision should not be allowed to reach the skin, on account of the bleeding which would ensue, but should comprise all the diseased tissues below the skin. This process should be repeated in all directions until the carbuncle consists of only a superficial covering of sound skin overlying the thoroughly divided and broken-up mass of the carbuncle, which should then be removed by curetting or in some other effective manner. The amount of hemorrhage is usually very slight. If the strength of the patient is not too much reduced, recovery is usually rapid and complete.

Warren maintains that a more radical form of operation should be carried out in many cases. He says: "The most radical treatment consists in total excision of the carbuncle. A circular incision should be made round the edge of the infected portion of the skin, and all the diseased tissues should be removed. The effect is immediate. The fever and delirium disappear and the pain is relieved."

Carbuncle of the lip often causes very grave symptoms. Evacuation of the contents and extirpation of the infected tissues should be carried out, and any simpler mode of treatment is here usually insufficient. This should be done from inside the mouth when possible on account of the diminished scar or deformity thus secured.

The application of heat, preferably by dry or moist compresses, should follow any operative measures. Should the necessity for disinfection arise, this may be accomplished by the use of chlorinated soda, which is preferable to carbolic acid on account of the somewhat greater danger of poisoning by this agent in carbuncle than in ordinary surgery, owing to the more extensive surface for absorption and the age and weakened condition of the patient. If it should become desirable to employ an antiseptic, a solution of mercuric bichloride or some other efficient agent of this nature, of which we now possess a considerable number, may be used in the wound.

The cicatrix following carbuncle is generally more or less depressed, and may at times become so retracted as to produce deformity, and occasionally to interfere with the functional activity of parts or organs (neck, jaw, eyelid, etc.). *Albert N. Blodgett.*

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CARCINOMA.—The carcinoma is a tumor which arises from epithelium and is formed of masses of epithelium growing in a connective-tissue stroma. It is further characterized by unlimited local growth and by giving rise to the formation of tumors of a similar structure in other parts of the body. The tumor may arise from the surface epithelium of the exterior of the body, from the epithelium lining the alimentary canal, from that lining the lung, or from the various involutions of epithelium constituting the glands. Tumors having all the characteristics of true carcinoma may also arise in places where no epithelial structures are normally present. Such tumors do not form an exception to the general rule of origin, for they arise from embryonic epithelium which in the course of development has become included in mesodermic tissue and cut off from connection with the epithelial surface. Examples of such tumors are found in carcinoma of the deep tissues of the neck originating from the epithelial remains of the branchial clefts, in carcinoma arising in the walls of dermoid cysts, etc. Tumors having a structure very similar to that of carcinoma may arise from the endothelium of blood and lymphatic vessels. The carcinoma may also arise from the germinal tissue of the ovary and the testicle.

It has long been known that all epithelial surfaces are not equally liable to carcinoma. In general, we find that the tumor is more likely to form about the orifices of the body where skin and mucous membrane come in contact, as in the lips and anus, or where the course of embryonic differentiation has been complicated, as in the lower third of the œsophagus. Carcinoma arising from the glands is particularly apt to occur in those glands which are generally inactive but which have the power of extreme proliferation and functional activity, as the mammary gland and the uterus. In certain places the occurrence of carcinoma is probably to be explained by the action of repeated traumatic stimuli, but the influence of trauma in producing carcinoma as well as other tumors, has probably been greatly overestimated.

On microscopic examination the carcinoma is found to be composed of two kinds of tissue: first, epithelial cells arranged in masses which vary in size and form, and which are enclosed in spaces called alveoli; secondly, connective tissue which surrounds the alveoli and bears the blood-vessels for the nutrition of the cells in the alveoli. This connective tissue is called the stroma. Neither stroma nor blood-vessels penetrate the epithelial masses. Normal epithelial structures show a similar arrangement of tissue, epithelial cells growing in the closest juxtaposition with connective tissue, but the latter never penetrating between the cells. Whether we consider the covering epithelium or the glandular epithelium the arrangement of the tissue is the same.

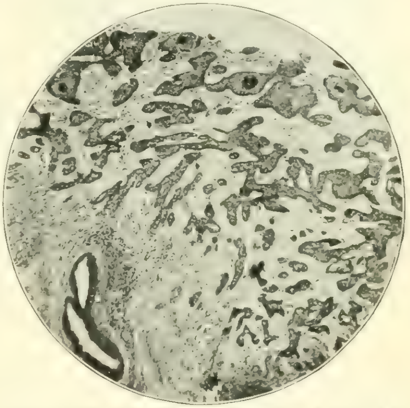

FIG. 1117. Small Carcinoma of Forehead Showing Network of Epithelial Cell Masses Surrounded by Connective-Tissue Stroma. (No. 3 Leitz, without eyepiece.)

If, in the normal epithelial structures, the cells at some point begin to multiply and penetrate into the adjoining connective tissue, the structure of carcinoma is produced. The mere proliferation of the epithelium does not produce the carcinoma. Epithelial tissues are the most active of any tissues of the body. Both the covering and the glandular epithelium are constantly used up in the course of their physiological activity, and the loss is as constantly repaired by the formation of new epithelial cells. This power of regeneration is sufficient not only for the ordinary wear and tear of the tissues, but also for the repair of even extensive losses. Furthermore, the epithelium may be excited to greater activity by various means, and large masses of tissue composed principally of epithelium may be produced. Such a growth of epithelium is constantly accompanied by a growth of young connective tissue bearing blood-vessels. An epithelial growth of this character repeats in a general way the structure of the normal tissue and is called typical, but there is no normal prototype for the structure of the carcinoma. The penetration of the connective tissue by the epithelium is atypical. It is possible, however, to have such an atypical growth of epithelium giving the general structure of the carcinoma without the other characteristics which constitute the tumor. When the proliferating epithelium comes in contact with a loose cellular connective tissue, such as is produced by chronic irritative conditions, it may grow down into it, thus constituting an atypical growth. Such conditions are found around the edges of chronic ulcers of the skin and in other conditions. The growth of the epithelium may be very active, but it will extend only to the limits of the altered connective tissue.

When we compare the epithelium in different parts of the body we find differences in the size and form of the epithelial cells and in their arrangement. These differences are to a certain extent apparent in the carcinomata which arise in different parts, and from the histological examination of the tumor we can say with considerable accuracy from what epithelial tissue it has arisen. From this it is possible to divide the carcinomata into three great classes, originating respectively from squamous, from cylindrical, and from cuboidal glandular epithelium.

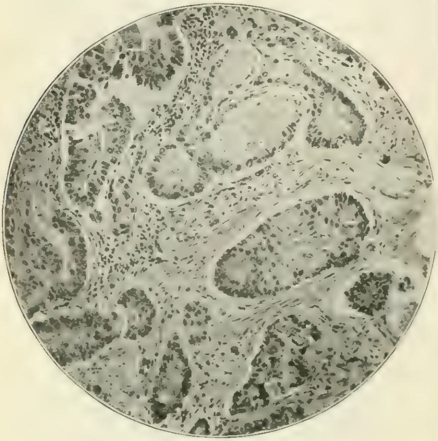

FIG. 1118. Carcinoma of Stomach, Involving the Submucosa, and Showing Masses of Cells Lying in Spaces Lined with Flat Cells. (8 mm. Zeiss.)

To explain the growth of the carcinoma it is necessary to consider the structure of the connective tissue. This is formed of fibres between which there are cells. It carries in it the blood-vessels and lymphatics. The cells lie in spaces in the tissue which communicate with adjoining spaces, and from the enlargement and coalescence of these spaces the lymphatics arise. If the carcinoma begin by the proliferation of epithelium, the new cells not passing to the surface as in a typical growth but into the connective tissue, they must at once enter into this system of communicating spaces and continue to grow in them. Every mass of epithelial cells is within a lymph space in the tissue. It is easy to show this in various ways. The epithelial masses follow the general direction of the lymphatics. In a carcinoma of the skin the most superficial epithelial masses have a general direction perpendicular to the surface, while those lower down are horizontal, corresponding to the course of the lymphatics. By staining the fresh tissue with nitrate of silver and washing out the cells, a lining of endothelial cells similar to that lining the lymphatics can be shown in the alveoli. In hardened sections the cell mass often shrinks away from the wall, and the flat nuclei of the lining cells can be demonstrated.

It will scarcely be possible to give any general description of the epithelial cells constituting the main mass of the tumor. Their resemblance to the normal epithelium from which they have arisen is much more apparent when they are examined in mass than when the single cells are compared. Both the protoplasmic body of the cell and the nuclei are, in general, larger. There is enormous variation in shape due to the pressure to which they have been subjected. Degenerative processes of various kinds are apparent in the protoplasm. Vacuoles filled with fat, or hyaline droplets, are often seen. Various cells, such as polynuclear leucocytes or lymphoid or plasma cells, and even red blood corpuscles, are frequently found enclosed within them. The enclosed cells lie in vacuoles and may be so well preserved that their character may be recognized, or they are only represented by degenerated fragments. There is a marked difference in the character of the nucleus as compared with the normal. It is larger, stains more actively, and is rich in chromatin. The cells often contain several nuclei and may approach the character of giant cells. Occasionally single cells of great size and irregularity of form, containing a single immense nucleus, may be found. If the process of cell division as shown by the nuclear figures be studied the same irregularity is seen. In the place of the simple division into two nuclei the most complicated nuclear figures, showing simultaneous division of the nucleus into a great number of daughter nuclei, may be found. The examination of the single cells shows almost as great a departure from the normal type as does the tumor considered as a whole. All the changes found in the cells are indicative of very active growth. This is necessarily accompanied by degenerations of all sorts, for the closely packed masses of cells cannot obtain sufficient nutrition.

The examination of the masses of epithelium lying in the alveoli shows great variation in size and shape. Serial sections of young tumors, especially those of the skin, show that the epithelium for the most part forms a solid mass ramifying in the connective tissue. In the periphery small epithelial masses may be found which have no connection with the main mass. In the glandular carcinomata the connection between different parts of the epithelial mass exists to some extent, but is not so evident as in the small carcinomata of the skin. Generally there is a sharp separation between the epithelium and the surrounding stroma, but in places it may be difficult to make it out. When the stroma is rich in cells some of these may be very similar to the epithelium, and it is difficult to distinguish the limits of the epithelium when growing into such a cell mass. It is often impossible to distinguish single epithelial cells separated from the main mass and growing between the cells of the stroma. When the growing carcinoma invades a loose connective tissue, the cells penetrate in all directions, growing without any regularity, and the arrangement into cell masses and stroma may be lost. This is seen in the invasion of muscle. The epithelial cells grow in the

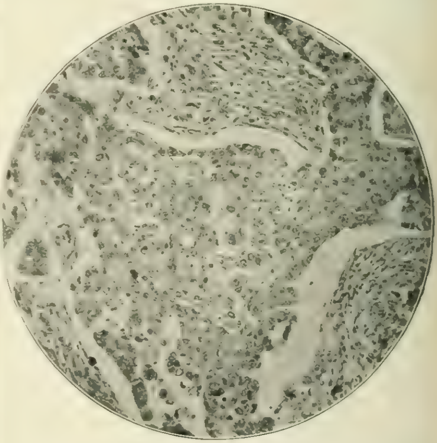

FIG. 1119.—Large Alveolus from a Carcinoma of the Breast with Numerous Cell Inclusions. These inclusions are not to be confounded with the supposed parasites described by Plummer and others. (8 mm. Zeiss.)

most irregular manner in long rows between the muscular fibres and in the loose connective-tissue septa. It is also seen to a less degree in the invasion of fat, the cells at first growing in the connective-tissue framework between the fat cells and afterward filling up the spaces. The cells of a skin carcinoma have a much greater tendency to adhere together, and there is a much sharper separation into cell masses and stroma, than is the case in the glandular carcinoma. The cell masses vary greatly in size; in some cases they are large with but little stroma between them, in others they may be reduced to simple rows of cells in a dense stroma. These two forms are known as medullary and scirrhous carcinoma. We may commonly find both types in the same tumor, one or the other predominating. Proliferation takes place almost exclusively in the cells on the outside of the mass. These cells are in contact with the stroma carrying the blood-vessels for their nutrition, and are larger, and the nuclei richer in chromatin, than the cells in the interior. By the increase of the mass in size, the cells in the interior are removed further from the source of nutrition and degenerate. Very often the interior of the mass is a cavity filled with degenerated and necrotic cells. The forms of the cells may be preserved or they may soften and the individual cells can then no longer be recognized. In such cases the softened material usually contains great numbers of polynuclear leucocytes. The softening may extend to the periphery, and not only leucocytes but connective-tissue-forming cells may enter the mass and a process of organization take place leading to the absorption of the necrotic tissue which is replaced by young connective tissue. When this is the case a mass of growing connective tissue may

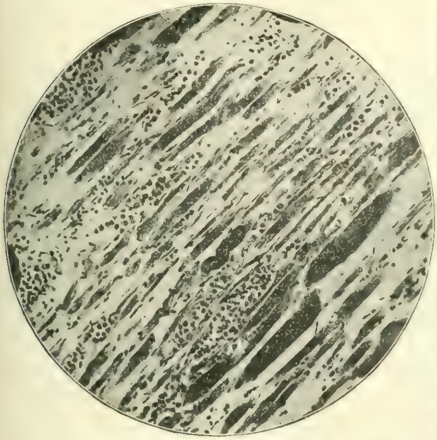

FIG. 1120. Longitudinal Section of Pectoral Muscle Invaded by Carcinoma of Breast, Showing the Masses of Epithelial Cells Partly Between and Partly Within the Muscular Fibres. The muscular fibres are atrophied and some of them necrotic. (8 mm. Zeiss.)

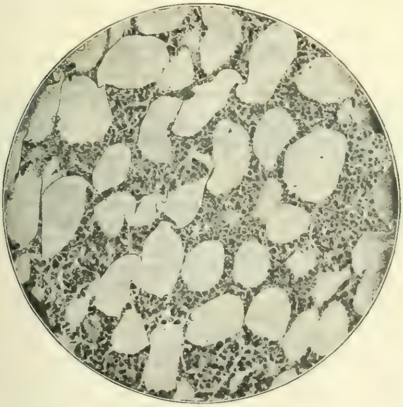

FIG. 1121.

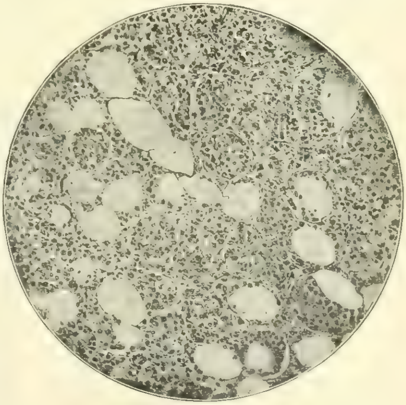

FIG. 1122.

FIGS. 1121 AND 1122.—The Invasion of Fat by Carcinoma of Breast. In Fig. 1121 the Epithelial Cell Masses are Chiefly Between the Fat Cells. In Fig. 1122 the fat has largely disappeared and the spaces are filled by the epithelial cells. (8 mm. Zeiss.)

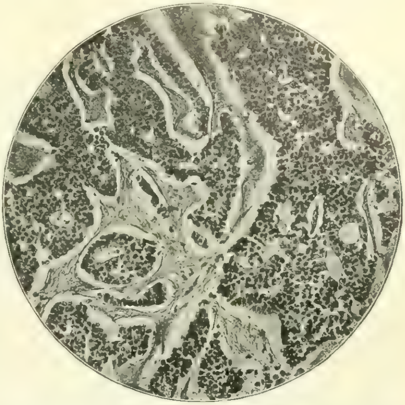

FIG. 1123.—Section Through the Periphery of a Carcinoma of the Breast, Showing the Medullary Type of Tumor. There are large epithelial masses and a small amount of stroma. (8 mm. Zeiss.)

be found within the alveolus surrounded by epithelium. Occasionally single blood-vessels surrounded by a small amount of connective tissue may push their way from the stroma into the mass of epithelium.

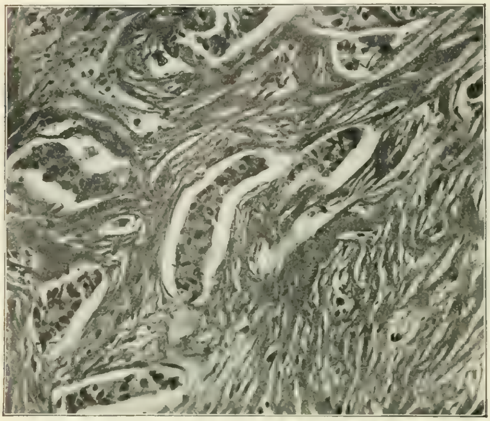
FIG. 1124.—Section from Centre of Same Tumor Showing Scirrhous Type. There are small masses of epithelial cells which are to a large extent degenerated, separated by a dense hyaline cicatricial stroma which contains few cells.

The epithelial cells of the tumor retain to a marked degree the physiological properties of the cells from which they are derived. In a carcinoma of the skin the cells around the outside of the alveolus have the properties of the Malpighian layer, and the central cells represent the horny layer. Proceeding from the periphery of the alveolus to the centre the eleidin granules begin to appear, and, finally, the cells become flattened and converted into keratin. The flat, horny cells are subject to pressure from all sides, and in consequence concentric masses of horny cells are formed which have been called *epithelial pearls* or *onion bodies*, and which form one of the distinguishing features of carcinoma of the skin. A more interesting example of this tendency to the physiological type is seen in the cylindrical-cell carcinoma, which forms one of the most common tumors of the lower alimentary canal. In these tumors the epithelium rarely forms solid masses filling the alveolus. When these cells enter into a lymph space in the tissue they tend to grow in the same manner as in the normal structure—that is, in close contact along their long axes. In consequence of this the spaces become lined with cylindrical cells simulating a normal gland structure with a lumen in the centre. In consequence of the continued active proliferation groups of cells retaining their form and mode of growth become forced into the centre of the space, and grow there, forming complicated loops or round masses with a central cavity. These tumors so greatly resemble the adenomatous or true glandular tumors that they are often called by this name, or their malignant character is expressed by the term adeno-carcinoma or malignant adenoma. They do not differ from the carcinoma in other situations save in the character and the arrangement of their cells. The same tendency to a normal arrangement of cells may be seen in such a typical carcinoma as that arising in the mammary gland. Within the single alveoli of this, peculiar round spaces are often seen among the cells (Fig 1123). These are generally interpreted as being formed by the degeneration and absorption of certain cells. No remains of such cells are found within the spaces, nor can the steps in their formation be followed. The cells on the outside of the small cavity have a definite arrangement with their long axes parallel. In other cases spaces very similar to these may be found containing connective tissue and blood-vessels, which represent strands of the stroma that have become surrounded by the growing epithelium, and thus included in the cells mass. It is probable that cavities may be formed by the degeneration and absorption of such masses of connective tissue. In other cases careful examination will show that the epithelial cells within the alveolus are arranged in rows with their long axes in contact, though the rows of cells are distorted from pressure. Most of the cavities and the arrangement of the cells in rows and columns are due to a tendency of the cells to follow their physiological mode of growth. Such tendencies are more especially seen in those tumors in which the growth is slower; in these the newly formed cells keep up their nutrition longer and have time to attempt a typical arrangement. It may be found in one part of the tumor and be absent in another part. I have seen a typical scirrhous carcinoma of the breast with central degeneration and diffuse extension into the surrounding tissue. On one side of this, apparently growing out from it, was a tumor of a totally different character, of the size of a hen's egg. This tumor was softer, more homogeneous, and more vascular than the scirrhous. It was sharply circumscribed and did not infiltrate the surrounding tissue. On section it was found to be composed of large alveoli filled with well-preserved cells. There were numerous large, round, and oval spaces in each alveolus. The metastases in the axillary lymph nodes were of the scirrhous type.

The character of the stroma varies nearly as much as does that of the cell masses. It forms a part of the tumor and grows with it, a large part being undoubtedly newly formed. In part, it represents the old connective tissue which has been invaded by the epithelium. All the constituents of the normal tissue which have been invaded are

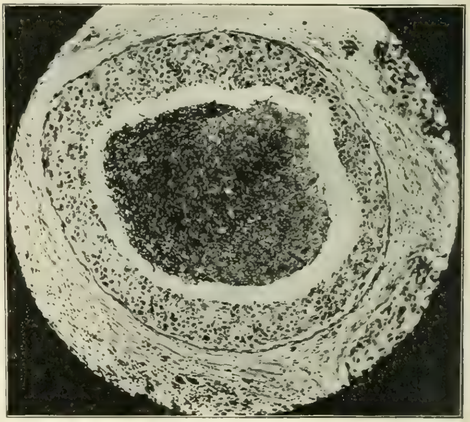
FIG. 1125.—Large Alveolus from Carcinoma of Breast with Central Mass of Degenerated Cells. There are large numbers of leucocytes in the necrotic mass. (8 mm. Zeiss.)

EXPLANATION OF
PLATE XX.

EXPLANATION OF PLATE XX.

Fig. 1.—Cylindrical-cell carcinoma of rectum, showing the invasion of the submucous tissue and muscular coat. × 20.

Fig. 2.—Section of epithelial carcinoma of tongue, showing the invasion of the muscle by long thin processes of carcinoma cells. The muscular fibres are cut transversely and show various degrees of atrophy. × 150.

Fig. 3.—Extension of carcinoma by implantation. Section of a nodule on the surface of the peritoneum secondary to carcinoma of the ovary. The tumor growing on the surface has formed vascular connections with the peritoneum, but has not penetrated the tissue. × 50.

Fig. 4.—Section through a small carcinoma of the breast, showing the rapid peripheral extension and the central atrophy. The darker areas show the places where the cells are most abundant. × 10.

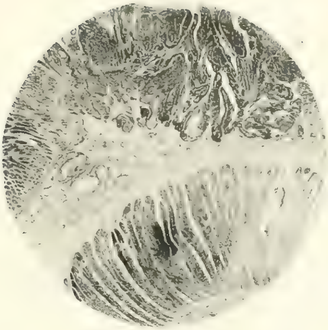

Fig. 1

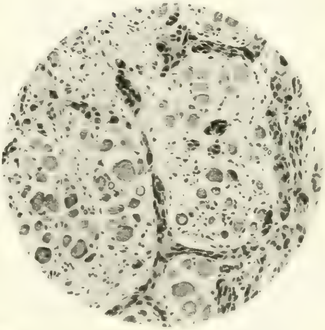

Fig. 2

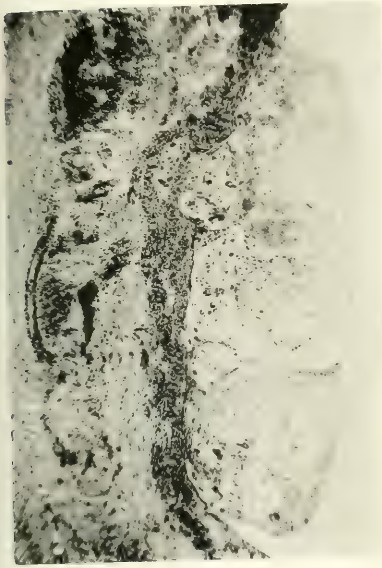

Fig. 3.

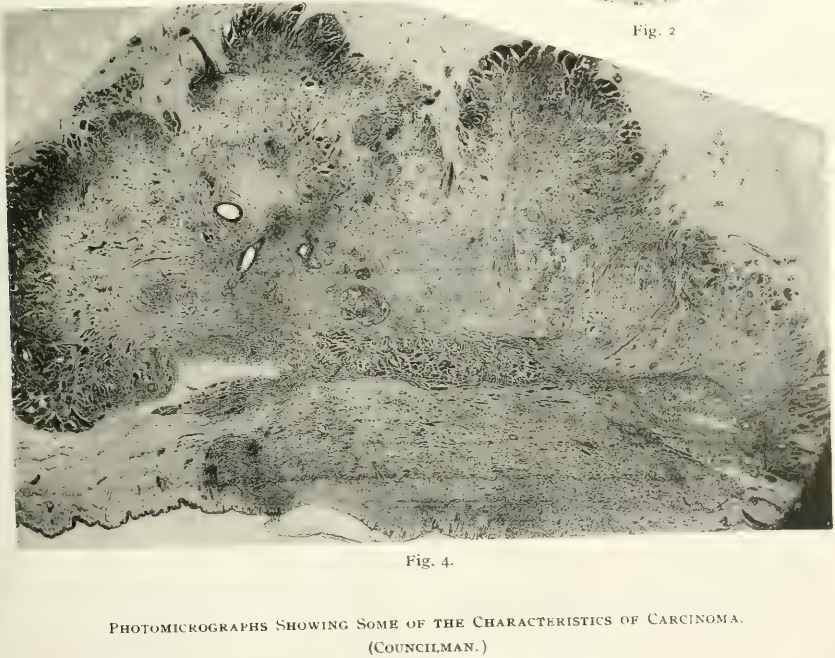

Fig. 4.

PHOTOMICROGRAPHS SHOWING SOME OF THE CHARACTERISTICS OF CARCINOMA.
(COUNCILMAN.)

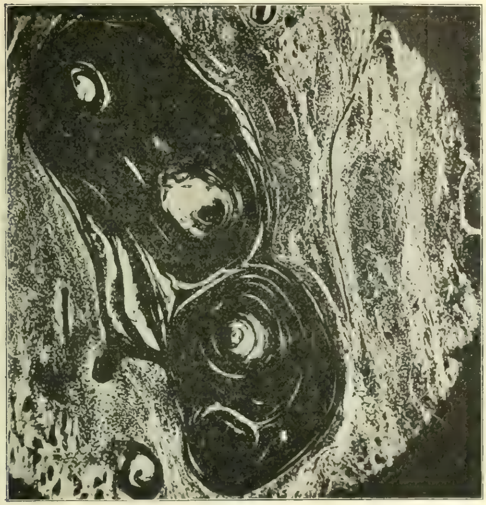

FIG. 1126. Large Epithelial Pearl from Carcinoma of Tongue. The section was stained with iron haematoxylin which colors the keratin an intense black. (8 mm. Zeiss.)

contained in the stroma. In a carcinoma of the skin the stroma contains sweat glands, and in the mamma atrophic glandular tissue. It also contains nerves and blood-vessels. We may partly explain the new formation of stroma as a formation of tissue to carry new blood-vessels to the masses of epithelium which demand nutrition, just as the interstitial tissue is formed in a developing gland. In part, it is due to the presence of the epithelial cell masses acting as foreign bodies. In some cases it contains large numbers of cells, in others but few are present. The most numerous cells in it are small round cells corresponding to the lymphoid cells of the blood and of the lymph nodes. These are found both as a general infiltration of the tissue and in small circumscribed masses somewhat resembling lymph nodules. These cells are usually found in the greatest numbers in the periphery of the tumor, and may even form a compact mass into which the tumor grows. Next to these cells, the plasma cells are most numerous, and are more generally present in carcinomata of the skin. There are also evidences of proliferation of the connective-tissue cells, but these are not present in very great numbers and are concealed by the infiltrating cells. In a carcinoma of the uterus, where the cells grow out into a tissue composed of smooth muscle fibres, the stroma is formed of muscular tissue. The stroma should not be considered an integral part of the tumor, but it is only an accidental growth due to the mode of development and growth of the tumor. Although the connective-tissue cells in it are usually not very numerous, they may be so abundant that the stroma resembles the tissue of a sarcoma. Mucoid and other degenerations of the stroma are not uncommon. The relation between the stroma and the epithelial masses may be affected by the rapidity of growth of these. When the alveoli are numerous, by their constant enlargement the stroma may be reduced to mere shreds of connective tissue which lie within the cell masses, giving the tumor, or certain foci in it, the appearance of a sarcoma. In the scirrhous type the stroma changes its character, becoming converted into a tissue similar to cicatricial tissue. In this the cells are very few, the fibres are fused together and hyaline. Giant cells are sometimes found in the stroma. Their formation here is analogous to their formation around foreign bodies, and is a point in favor of considering the stroma a growth excited by the epithelial cells acting as foreign bodies. They are found especially in carcinoma of the skin, in the vicinity of large epithelial pearls which sometimes occupy almost the entire alveolus, and the giant cells often contain the single scales of horny epithelium. Numbers of large epithelioid cells may be found in the vicinity of the giant cells, the group somewhat resembling a miliary tubercle.

The growth of the carcinoma as a whole is analogous to that of a single alveolus. This can be best studied in sections which are made through small tumors (Plate XX., Fig. 1). The most active growth is found in the periphery. The alveoli here are round or oblong, numerous, and the cells show but little degeneration. In the centre the alveoli are very small and angular, the cells are small and degenerated, and there are but few nuclear figures. In places the alveoli have disappeared altogether, and there is a dense hyaline cicatricial tissue and a depression is formed corresponding to the atrophic centre. The atrophy of the centre is partly to be explained by the compression and occlusion of the blood-vessels by growing epithelial masses between which they must pass, and

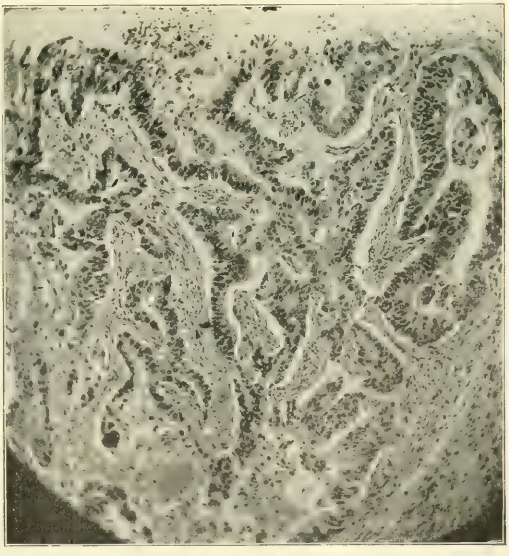

FIG. 1127. Section of Carcinoma of Stomach. The cells have a general cylindrical type and are arranged around the walls of the spaces. (8 mm. Zeiss.)

partly by the active peripheral growth consuming the nutriment. The centre of the tumor often shows the most typical scirrhous character, while the periphery has the medullary type.

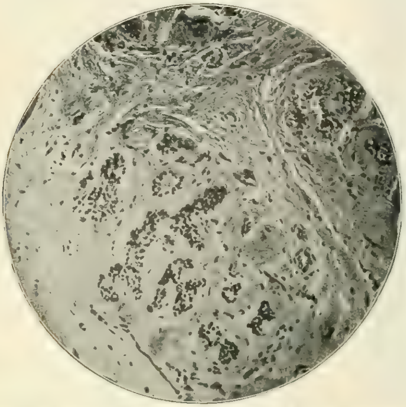

FIG. 1128.—Atrophic Glandular Tissue from the Stroma of a Carcinoma of the Mamma. (8 mm. Zeiss.)

The boundary of the tumor is never sharp (Plate XX., Fig. 1); it extends in lines into the surrounding tissues. Small masses are found in the vicinity either separated from or connected with the main tumor by a thin line of tissue. There is never any formation of a capsule, and from the nature of the tumor—a mass of epithelium growing into the lymph spaces and lymphatics—it is impossible that there should be a capsule formation. The advancing cell masses are often surrounded by infiltrating cells, but they may be found in tissue perfectly normal. Growing as it does, the tumor enters into a tissue, and the essential constituents of the tissue give way before it. The destruction and invasion of tissue in contact with it is one of the most marked characteristics of the carcinoma. The destruction of the tissue does not seem to be brought about by the pressure exerted by the growing cells, nor do the invading cells remove it by phagocytosis. This process can best be studied in the skin and in muscle. When the tumor extends toward the skin this usually becomes thin and atrophic before coming into actual contact with the cell masses. The cell layers diminish in thickness until there may be but a series of two or three cells below the horny layer. No nuclear figures are seen in the cells. Occasionally in a few places single carcinoma cells and even single groups of them may be found within the cells of the epidermis. The skin over the tumor is not elevated, but more generally depressed. The atrophy of the skin is due to the demands for nutrition made by the advancing tumor. No new cells are formed, and the old cells gradually become horny and are cast off. Where the tumor enters into the dense connective tissue of the skin there is usually a peculiar relation of cells and stroma. The small lymph spaces of the skin here cannot dilate under the pressure of the cells infiltrating it, so that there is an interlacing system of small alveoli filled with epithelial cells lying in a dense unchanged stroma. There is usually no appearance suggestive of new formation of stroma. In contact with the muscle, as where a carcinoma of the breast comes in contact with the pectoralis major, the tumor extends first along the connective-tissue septa and coarsely infiltrates the muscle. In places the growth is more rapid and small nodules may be formed in addition to the general infiltration. At this stage the muscular fibres are small and atrophic. Later there is extension between the fibres themselves. The fibres lose their striation and are converted into hyalin. In places the degenerative increase in the nuclei is prominent. Phagocytic giant cells may be formed in the stroma and these take part in the absorption of the necrotic fibres. The epithelial cells may push their way into the sarcolemma and extend within this. A section through such a place shows a general infiltration of epithelial cells arranged with some regularity in long lines parallel to the muscular fibres, and among them, small, generally angular remains of the fibres may be seen. The epithelial cells infiltrate the loose tissue, and there is no sharp distinction between cells and stroma. The same process of atrophy and gradual disappearance of tissue is seen in the extension of the tumor into such a parenchymatous organ as the liver. There is more evidence of the effect of pressure here than elsewhere. The liver cells in the vicinity are usually flattened or have a cylindrical form. In some cases, especially where the extension is very rapid, there is but little evidence of pressure even here. When the tumor comes in contact with the fat it extends in the larger connective-tissue septa, then along the fine septa between the fat cells. These become reduced to small spaces which finally disappear, the cells of the tumor filling the entire tissue. There is but little stroma in the tissue. Nothing shows better how little part the stroma plays in the tumor than the study of the periphery of a rapidly growing tumor. The abundance of the stroma has a direct relation to the amount of connective tissue in the tissue invaded. Different tumors vary enormously in the degree of their infiltration. One occasionally sees tumors in which the growth is almost as homogeneous as is that of a benign tumor, in which it is almost possible to determine the limit of the growth by the naked eye. As the direct opposite to these are tumors with such extensive infiltration that small extensions may be found far beyond what appears to be the periphery.

Not only is there this general growth by infiltration but small nodules of the tumor are found in the surrounding tissue, this being termed dissemination. These small nodules may be connected with the main mass by small lines not visible to the unaided eye, or they may be independent. They are found in carcinoma of the breast, more generally beneath the skin than in the deeper tissue. They repeat all the characteristics of the main tumor. Their presence is easily explained by a careful examination of the tissue in the vicinity of the tumor. This often

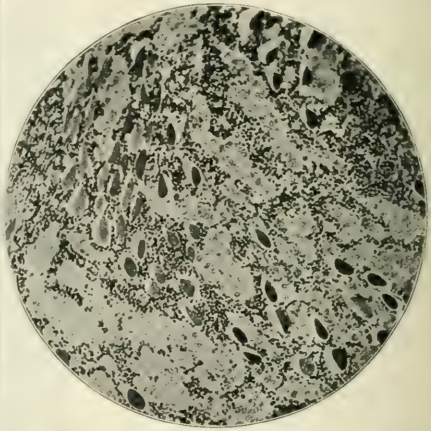

FIG. 1129.—Pectoral Muscle Invaded by Carcinoma of the Breast with great Numbers of Lymphoid Cells in the Stroma. The larger dark areas represent the atrophied muscular fibres cut obliquely. (8 mm. Zeiss.)

shows dilated lymph vessels filled with small masses of epithelial cells, or, in some cases, with single cells. I have sometimes been able to see the beginning of a peripheral nodule in an extension of the epithelial growth from such a vessel into the surrounding tissue. The cells are carried passively in the lymph stream. Examination of the fresh tissue of a carcinoma on a warm stage shows that the cells have slight amœboid movement, limited to the extension and retraction of processes. There is no evidence of such an extent of amœboid movement as would lead to a voluntary progression of the cells into the tissue, nor is it necessary to assume such to explain these secondary nodules.

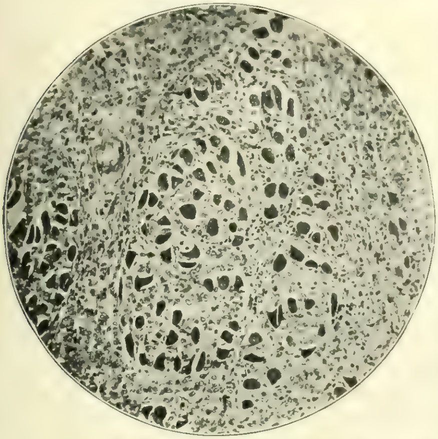

Fig. 1130.—Cross Section of Muscular Fibres Invaded by Carcinoma. The fibres are small and irregular in shape. (8 mm. Zeiss.)

It is characteristic of the tumor not only to grow by infiltration and dissemination, but small tumors similar to the original are formed in distant parts. These are termed metastases. They are due to the conveyance of tumor cells, by means of lymphatic and blood-vessels, from the primary tumor and their deposit in the places where the metastases appear. The relation between the epithelial masses and the lymphatics is so close in the carcinoma that the metastases appear first in those lymph nodes into which the lymphatics of the tissue in which the primary tumor is seated enter. Thus in carcinoma of the breast the first metastases are in the axillary lymph nodes, in carcinoma of the uterus, in the post-mesenteric lymph nodes, etc.

We have already spoken of the fact that single tumor cells and small connected masses of them may be found in lymph vessels in the vicinity of the primary tumor.

The affected lymph nodes are enlarged and may contain small, grayish masses or be entirely converted into tumor. They may be affected and yet show to the naked eye no evidence of this. So general is this secondary affection of the lymph nodes that surgeons in all cases of operation for carcinoma of the breast remove the axillary nodes. Microscopic examination of the nodes, particularly those which to the naked eye show no lesion, often give clear indications of the manner in which the infection has taken place. The metastasis begins in the periphery of the node at the place of entrance of the afferent lymphatics. These are often dilated and contain masses of tumor cells. There may be one or a number of small tumor foci in the periphery of the node in immediate relation with the lymphatic sinuses, or these may be generally injected with tumor cells. The peripheral sinus of the node is not infrequently seen filled with growing masses of the tumor which from here extend into the lymph nodules. Between the masses of epithelial cells there is in the beginning only the lymphoid tissue of the node. After this atrophies, its place is taken by connective tissue. The character of the original tumor is repeated in the metastases, although in general the cells of the metastatic growth show less of a physiological tendency than do those of the original tumor. In the metastases of carcinoma of the skin the tendency to pearl formation is less marked, and in those from glandular carcinomata the cells do not usually show the tendencies to physiological arrangement which may be marked in the primary tumor. The extension of a primary carcinoma into adjoining tissue may involve other sets of lymph vessels. When a carcinoma of the breast extends deeply into the tissue beneath, metastases may develop in the lymph nodes of the anterior mediastinum. Only the lymph nodes which are primarily connected with the original tumor may be affected, or the process may extend from these into adjacent nodes. The tumor growth may affect the entire node, and the cells find their way into the efferent lymphatics, or they may pass through the node by means of the lymph stream without producing a growth. In extensive metastatic formation in the axillary nodes the clavicular nodes also are usually involved. The detection, by microscopic examination, of metastases in the lymph nodes is usually easy, though in some cases the lymph sinuses are filled with large endothelial cells which have some resemblance to carcinoma cells and may be mistaken for these.

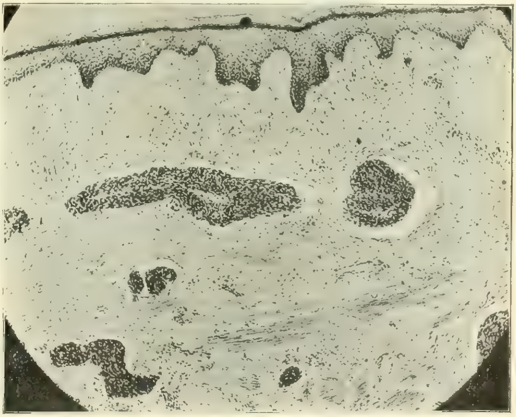

Fig. 1131.—Superficial Lymphatics of Skin Dilated and Filled with Masses of Carcinoma Cells. From a carcinoma of the scrotum with numerous metastases. (No. 3 Leitz.)

Metastasis by means of the blood circulation is less common in general than that which takes place by way of the lymphatics, although in carcinoma of the intestinal canal the former mode of disseminating the disease is the rule. The tumor cells may enter into the blood by means of the lymph circulation, or there may be a direct growth of the primary tumor into the blood-vessels. In carcinoma of the liver a growth of the tumor into the portal and hepatic veins is so common that it may almost be regarded as the rule. The frequency of metastases by blood-vessels in carcinoma of the intestinal canal is probably to be explained by the presence, in the latter situation, of numerous and thin-walled veins, which offer less resistance to the extension of the tumor into them. Where the metastases take place depends upon the distribution of the blood-vessels coming from the part. The metastases transported, by way of the blood channels, from the primary tumors of the intestinal canal, are found in the liver, while those coming from tumors in other parts of the body are found in the lungs. There are certain exceptions to this because the tumor emboli may pass like other emboli in the direction opposite to that of the blood current. Thus metastases may be found in the liver secondary to carcinoma of the lung, or in the kidney secondary to carcinoma of the liver. In these cases the emboli are probably larger and are carried by the force of gravity in the reverse direction to that of the blood stream. Very interesting combinations are often found of metastases by both blood and lymph circulation. Thus I have seen in carcinoma of the uterus metastases in the post-mesenteric lymph nodes, and from these a growth of the tumor into the thoracic duct, converting this into a large carcinomatous cord which extended into the subclavian vein. There were numerous very minute metastases in the lung simulating miliary tubercles, and from these extension had taken place into the subpleural lymphatics, which were actually injected with the tumor masses, and into the bronchial nodes. The metastases by way of the blood-vessels may be single or so numerous as to simulate a case of acute miliary tuberculosis. In such cases the condition is spoken of as a general carcinomatosis.

Extension of the tumor may also take place at various places on the surface, due to the implantation of masses of a tumor along an adjoining surface (Plate XX., Fig. 4). We find examples of this in the appearance of numerous nodules on the surface of the peritoneum in carcinoma of the ovary which extends to the peritoneum. Such metastases are most apt to be found in those situations where solid particles are carried by the force of gravity. There may also be extension by implantation along the surfaces covered by epithelium. In carcinoma of the kidney tumors may be found along the course of the ureters or in the bladder. In carcinoma of the ovary they may be found in the Fallopian tubes. The carcinoma often shows a marked tendency to extension along the course of the nerves by means of the perineural lymphatics. The nerve as a whole may be surrounded and compressed by masses of epithelial cells or these may be found between the single nerve fibres. In carcinoma of the tongue involvement of the inferior maxillary branch of the fifth nerve is common. The extreme pain which so often accompanies carcinoma can be explained either by extension of the tumor into the nerves or by their compression in the contracting stroma. Tumor cells are rarely found free in the blood-vessels as they are in the lymphatics, but are usually associated with thrombi, and the main mass included in the thrombus may be degenerated. I have frequently found a vessel entirely occluded by a mass which was composed of fibrin and necrotic tumor cells, and along the wall of the vessel, where they could obtain nutrition from without, there could be seen a line of growing cells. In one case of carcinoma of the breast I found a small, round mass of epithelial cells, the centre of which was degenerated and filled with leucocytes, around this a small layer of fibrin, and on the outside evidently circulating blood. Such a mass was probably broken off from a fresh tumor thrombus and may have been actually in process of transportation.

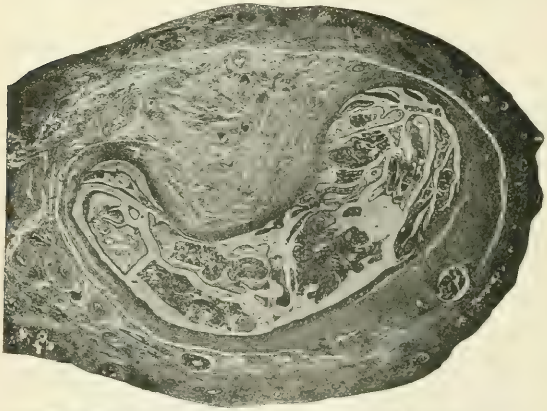

FIG. 1132.—Section of Ovarian Tube in a Case of Carcinoma of the Ovary. There are numerous tumor masses both in the wall and in the lumen. The involvement of the tube was most marked at the distal end. The process probably began in the lumen and from this extended into the wall. (80 mm. Leitz.)

It is important to determine, in carcinoma, whether the tumor originates in single cells or groups of cells which continue to grow, or whether it starts from a comparatively large area of tissue, or, finally, whether tissues of a similar character coming in contact with the growth can develop the same tendencies. It is very difficult to determine these points by microscopic examination. In carcinoma of the skin we undoubtedly often find large areas of epidermis in direct association with the tumor. It is also possible to find the epidermis in the vicinity of the tumor, but not immediately connected with it, apparently taking part in its growth, and growing in the same manner. The same thing is true in carcinoma of other epithelial surfaces, as in the alimentary canal. Here we often find the tumor in continuity with the glands over a large extent of the surface, the glands apparently growing into the tissue beneath and branching in this. Ribbert, who holds that the origin of the carcinoma is due to the separation of single epithelial cells and their inclusion in the connective tissue, believes that this connection of the tumor with the epithelial tissues is really secondary, and due to the extension of the tumor to the surface with the formation of a connection between the cells of the tumor and the epithelial surface. It is certainly true that when metastasis takes place the parenchymatous cells of the organ invaded take no part in the growth. Thus, in the secondary nodules in the liver, the liver cells are never converted into those of the tumor. When a glandular carcinoma comes in contact with epidermis, although this may actually be invaded by the single cells of the tumor and be in contact with tumor epithelium, there is no transformation. In a carcinoma of the breast the glandular tissue is usually atrophic. The tumor tends to extend along the ducts which may be surrounded by lymphatics filled with tumor cells, and yet the epithelium of the duct may show no change. In other cases the epithelium certainly appears to take part in the growth. There may be a simple proliferation of epithelium leading to the formation of projecting papillary masses within the duct, or in combination with this there may be an outward growth of the epithelium into the surrounding tissue. The cells change their character, becoming larger and taking on all the characteristics of the tumor cells. Undoubtedly, for most of these conditions the explanation of secondary tumor extension given by Ribbert applies. In favorable sections, and especially in series of sections, the tumor evidently extends from the outside into the duct, and the tumor epithelium grows over or replaces the epithelium of the duct. It is often possible to distinguish definitely between the epithelium of the duct and the tumor cells in connection with it. In other cases this explanation will not suffice. The clearest evidence of a participation of the general epithelial structures of a part in the growth of the tumor was given in a case of carcinoma of the skin, in which there were undoubtedly proliferation and outward growth of the epithelium of several hair follicles which were in the immediate vicinity of the tumor, but in no way connected with it. I have seen a similar condition in the ducts and alveoli in carcinoma of the breast.

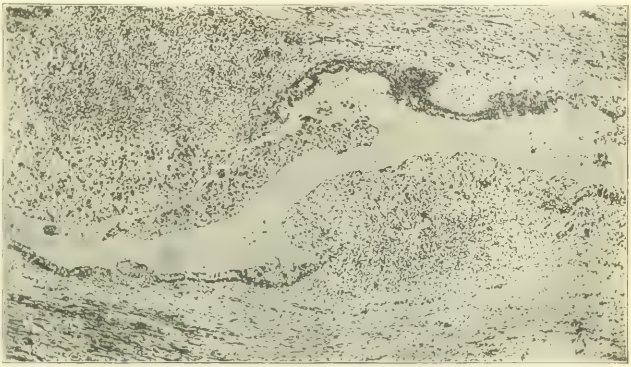
FIG. 1133. Longitudinal Section of a Large Duct in Carcinoma of the Breast. The cylindrical epithelium of the duct is partly preserved but in places it is covered by a growth of the carcinoma cells which extend into the lumen from the walls. (No. 3 Leitz.)

I have already spoken of the necrosis in the centres of the cell masses (Fig. 1125). In addition to this there may be more extensive necrosis involving either entire alveoli or masses of alveoli with stroma. Such necrosis is due to disturbances of circulation, usually by compression of arteries or veins, or both, by the growing tumor masses between which they run. In other cases it is due to the formation of thrombi. The necrotic tissue may remain, undergoing but little change, or it may be absorbed and its place taken by dense cicatricial stroma. The boundaries of the necrotic tissue are often extremely irregular, unchanged tumor tissue projecting irregularly into it. Hemorrhage may accompany the necrosis, but is not common. Where the necrotic tissue comes in contact with the surface bacteria may enter, producing gangrenous softening accompanied by suppuration. Ulceration is a common accompaniment of both the glandular and the surface varieties of carcinoma.

When the tumor extends to the surface the epithelium over this gradually disappears by atrophy, and the tumor appears as a raw uncovered mass resembling somewhat the base of an ordinary ulcer, although it is smoother and paler. There is always on the surface a thin line of necrosis due to the action of traumatic causes. In addition to this there is more extensive necrosis extending irregularly from the surface into the tumor tissue. The cells of the tumor at the surface are placed under more unfavorable conditions as regards their nutrition than are the cells in any other part of the tumor, for they receive their blood-supply from one side only, and constriction of the vessels is constantly going on. Necrosis due to this takes place and assists in the extension of the superficial traumatic necrosis. The necrosis is always assisted by the action of bacteria, and extensive gangrenous sloughs may be produced. There is continuous new formation of tissue pushing up from below, so that the ulceration is usually not deep and gives but little idea of the extent of the loss of substance. The destruction of tissue may be so extensive that in spite of rapid growth the resulting tumor may be insignificant in size. In carcinomata of the lip the surface of the tumor may appear as an ulcer somewhat depressed, or be covered by a scab formed principally of a mass of cast-off epithelial scales. When a glandular carcinoma extends to the surface it is not usually covered by a scab, because but little exudation can find its way from the tissue beneath to take part in its formation.

Ulceration plays a very important part in carcinomata of the intestinal canal, especially in those of the stomach, and the results of the process differ somewhat from the results of the process elsewhere. The necrotic tissue is destroyed by the action of the gastric juice, leading to the formation of a smooth, clean ulcer, and the tumor grows in elevated masses around the edge of this. The process of necrosis may be so active that the ulcer may resemble a simple ulcer and only by microscopical examination of the edge can its character be determined. In other parts of the intestinal canal necrosis with resulting gangrene is more common, though we may have in the rectum carcinoma with ulceration, of the same character as that in the stomach. In the alimentary canal the contraction which so constantly accompanies the growth and which is due to the conversion of the stroma into cicatricial tissue, leads to constriction and occlusion of the lumen. The occlusion is assisted by the action of the elevated tumor masses around the ulcer.

Constitutional Effects.—The effect of a carcinoma on the individual remains to be considered. The most constant condition accompanying it consists in emaciation and the production of cachexia. The cachexia is probably due to a number of conditions. The malnutrition is due in the first place to the loss of sleep induced by pain. The absorption of the toxic products coming from the necrotic tissue may interfere with the nutrition and produce a condition of chronic toxæmia. To this must be added the absorption of toxic substances from bacterial action, and finally a general infection produced by bacteria which have invaded the tumor. The evidence of such conditions is seen not only in general degeneration of the organs but in such special degenerations as amyloid. Changes in the blood are unimportant. In the later stages there may be considerable diminution in the number of red corpuscles. The leucocytes may remain normal or show some increase, this particularly when ulceration is present.

Etiology.—The cause of carcinoma remains in absolute obscurity. A fair measure of our absolute ignorance of the subject may be found in the number of theories which have been advanced, each of which has its advocates and each of which is favored by certain conditions associated with the tumor. The first of these theories and the one which probably still has the most adherents is the traumatic theory which supposes the tumor to be due to the continuous action of an irritant which excites the cells to proliferation. Virchow has been the most prominent defender of this theory and many surgeons have supported it. Carcinoma of the lower lip, which is practically confined to males, is used in support of the traumatic theory, being supposed to be due to smoking. The development of carcinoma in the site of old cicatrices, particularly those resulting from burns, is also used in favor of the traumatic origin. Probably the facts of the infrequency of carcinoma in those parts of the body most exposed to trauma and its frequency in those parts least exposed are the strongest arguments against the traumatic theory. No parts of the body are so exposed to traumata of various sorts as the hands and feet, and yet the tumor is exceedingly rare in the former and almost never occurs in the latter. No parts of the body are less exposed to trauma than the mammary gland and the uterus, and the tumor is very frequent in these situations. Even in the pessary days of gynæcology, when the uterus was possibly the most abused organ in the body, carcinoma of this was not rendered more frequent. In the example given of the association of carcinoma of the lower lip and smoking, the infrequency of the tumor in the upper lip, in spite of the fact that this must be as much exposed to the traumatic or irritative action of the tobacco, is not explained. Carcinoma is not more frequent in those who by reason of occupation or conditions of life are more subject to traumata. Another example often cited to show the influence of trauma is the association between gall stones and carcinoma of the gall bladder. This tumor is about four times as common in women as in men, and lacing in association with gall stones is supposed to be a favoring cause. It is undoubtedly true that gall stones are constantly found associated with the tumor, but this may be due to the fact that their formation is favored by the production of necrotic tissue which may serve as a nidus in the formation of the concretion. It has also been urged that in cases of metastatic tumor formation in the gall-bladder calculi are not found, but here again the infrequency of ulceration and other conditions which would favor their formation must be considered.

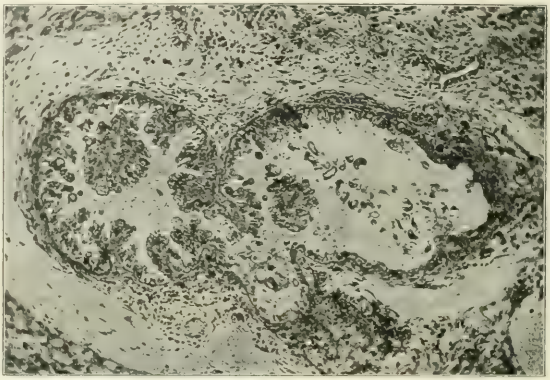

FIG. 1134. Bile Duct of the Rabbit from a Case of Psorospermosis of the Liver. The duct is dilated and partly filled with a papillary growth. The empty capsules are seen in the lumen. The younger forms are in the epithelial cells. (8 mm. Zeiss.)

It would not do to dismiss the influence of trauma in the production of the tumor as altogether incredible, but if it plays any part it must be a very minor one, or it may help in the action of other causes.

There is much that may be said in favor of the germinal theory of origin. This assumes that in the course of embryonic development remains of embryonic tissues may be included within the normal tissues, and from such embryonic remains, or from certain cells which have retained their embryonic capacity for growth, the tumor may develop. In favor of this theory it may be said that such remains of embryonic tissues do become included within normal tissues and from them tumors often develop. This theory, though not original with Cohnheim, was taken up by him and advocated with all the force and charm which characterize his work.

Ribbert has of late advanced a theory of formation which may be said to be a modification of the germinal theory. He supposes that not only such embryonic remains of tissue may be included in other tissues, but in the course of pathological processes epithelial cells may be separated from their connection with one another and enclosed in the connective tissue. The stroma, for him, forms an integral part of the growth, and the tumor usually begins with cellular infiltration of the connective tissue. There is much that is opposed to this theory of Ribbert's. The cellular infiltration around the edge of a young carcinoma, though commonly present, may be entirely absent. I have regarded it as due to the reaction of the connective tissue to the presence of epithelial cells out of place and which act as foreign bodies. It is not at all an uncommon thing in the course of surgical operations to have both collections of epithelial cells and single cells included in the connective tissue, as in the suturing of wounds of the skin or intestine, and the same thing probably takes place in any operation on a glandular organ. The cells may remain in the tissues for a considerable time and may even show evidences of growth, but they are finally destroyed by the phagocytic action of cells derived from the tissue. Another point against the theory of Ribbert is his assumption that the small-cell infiltration is indicative of activity on the part of the connective tissue and the cells are derived from this. They are really chiefly lymphoid and plasma cells, and the condition may not betoken any activity whatever on the part of the connective tissue. Boll, in 1876, spoke of the importance of the stroma in the carcinoma. He says also that in the development of the tumor there is marked proliferation of the connective tissue, leading to the formation of a vascular germinal tissue into which the epithelial growth takes place. He thinks that the formation of such a tissue is the one essential condition for the formation of carcinoma. When it is formed the old strife between the epithelium and the connective tissue breaks out anew. Thiersch, also, says that the frequency of carcinoma in old people may be due to degenerative conditions of the connective tissue which can no longer successfully oppose the growth of the epithelium. In this connection it must further be remembered that the epithelial cells of a carcinoma do not grow as does ordinary epithelium. The cells may retain something of their physiological tendencies as shown in their manner of growth, but they have a capacity for growth and an activity of growth far in excess of any normal tissue. Hansemann has called particular attention to the very marked difference in structure and in the manner of multiplication in the cells of the carcinoma as contrasted with normal epithelium. The enormous capacity for growth is not due to the abnormal situation in which the cells find themselves, but to certain qualities in the cells themselves. In their abnormal situation they are not placed in the most favorable conditions for nutrition, but in spite of this their growth is so rapid that the increase more than compensates for the cell destruction that takes place. Normal epithelium placed in the same situation shows only a limited power of proliferation and finally disappears.

This being the case, nothing was more natural than to suppose that some influence was exerted on the cells giving them other properties, and with this came the idea of the parasitic origin of carcinoma. In the first place, there seems much analogy between a carcinoma and such an infectious disease as tuberculosis. Both arise in some primary point, and from there the same process extends farther by means of the blood and lymphatic vessels. But the analogy does not go further. In tuberculosis the nodules are due to proliferation of the ordinary cells of the tissue and to exudation. The tissue formed has certain characteristics due to its arrangement and tendency to necrosis, but the same elements which compose it may be found in a variety of conditions. In carcinoma the new formation of tissue has a definite structure and could not arise from simple proliferation of the tissue elements. In infection of certain epithelial surfaces by protozoa there may be marked epithelial proliferation which may somewhat simulate a tumor, but the growth is typical and if the infection proceeds further the character of the formation in which it appears is modified by the character of the tissue. Examples of this are seen in the psorosperm infection of the alimentary canal and liver of the rabbit. In the infectious disease the pathogenic organism alone is necessary; in the carcinoma the cell is the infectious agent. The infectious disease may be transmitted from one individual to another. There is no evidence to show that carcinoma is ever transmitted from one individual to another under natural conditions, and even inoculation experiments which have been made from man to man and from man to animals have always been without any result. There have been cases, however, of successful inoculation from place to place on the same individual. In animals it has been possible to transfer carcinoma from one animal to another by implanting pieces of the tumor. Even if the carcinoma could be inoculated from man to man, or even from man to animal, it would be nothing in favor of its parasitic origin. When the disease once develops, when the epithelial cells once take on the peculiarities of growth which characterize the tumor, these cells are practically parasites. They live in strange situations and at the expense of the tissue which is their host, and have the power of unlimited increase. It might even be possible to suppose that favorable conditions for their increase might be provided outside of the body, and the disease might be transmitted by inoculation with generations of cells which have developed in vitro. It seems most remarkable that it is not possible to place these cells, still growing and contained in tissue, in another individual and have them retain their power. It is possible that there may be certain chemical differences in the tissue fluids of an individual with carcinoma which are favorable or essential for such a growth of the cells.

The carcinoma is easy of explanation after it has begun; the difficulty is in finding its primary cause. Ground for the assumption of a parasitic origin has been found in the supposed increase in the frequency of carcinoma. If it is due to embryonic causes or trauma or any such constantly acting cause, there should be no likelihood of increase. If due to parasites, carcinoma, like other infectious diseases, should show periods of increase and decline. There seems to be little doubt, from the numerous statistics which have been gathered on this subject, that there has been a marked increase in the mortality from carcinoma in the past twenty-five years. There are a number of things to be considered in connection with this increase. There has been an increase in longevity, due principally to diminished mortality in the infectious diseases. Carcinoma is essentially a disease of later life, and more people reach what may be termed the carcinoma age. The diagnosis of carcinoma, especially of the internal organs, has become more accurate and deaths are now properly attributed to this disease which were formerly put down under other heads. Deaths from carcinoma were formerly concealed as much as possible, due to a horror of the disease and fear of a supposed hereditary family taint being known. Hospital surgeons have a general idea that the disease is increasing, from the increased number of cases which come to the hospitals for operation, due to the much greater success which now attends such operations. There still remains a great deal of work to be done on the statistical side, with a careful consideration of the operation of other causes, before we can say how much the disease is increasing or if it is increasing at all. The increase as generally shown is not in favor of the parasitic theory, for it has been gradually progressive, and not marked by exacerbations and remissions as would be the case with an infectious disease.

Although from a theoretical point of view all that we know about the carcinoma would oppose the parasitic theory, the proof of this is believed by some to have been shown by the actual presence of parasites in the cells themselves. No consideration need be given to the old works on this subject, in which bacteria were found in cultures made from tumors. No connection was ever shown between the tumor and the bacteria and no results followed from inoculation. Following this there have been numerous descriptions of other organisms than bacteria, and attempts have been made to cultivate these supposed organisms and to reproduce the disease by inoculation. At first these problematical organisms were supposed to be protozoa, and in some cases the entire life history of the organisms was described. Since the work of Busse the protozoic idea has been given up and most of the present writers on the subject describe the organisms as belonging to the blastomycetes. All of these descriptions depend upon certain bodies which are included in the cell protoplasm. These bodies included in the protoplasm differ in their size, form, and staining reactions. There are certain among them which have about the same size and apparently the same structure, and these have been especially selected as being varieties of the yeasts. They are not universally present in all carcinomata. They are found more frequently in carcinomata of the breast than in those developing from any other part, and have seemed to me to be more frequent in those tumors and portions of tumors in which degenerations are more frequent. They are not present in carcinomata of the skin. These bodies are in the vicinity of the nucleus and as a rule they have about the diameter of a red blood corpuscle, though they may be much smaller or larger. In some cases they are as large as the nucleus of the cell. They usually have a sharp edge separating them from the protoplasm and occasionally a small space may be seen at one side, but they do not lie in definite vacuoles. They have a homogeneous, non-granular structure, and usually there is a single granule in the centre of about the size of the nucleolus of a cell and which stains in the same manner. Not infrequently there are radiating lines which extend from the central granule to the periphery of the body.

Plimmer, an English investigator, has laid great stress on these bodies and regards them as the specific organism which produces the tumor. The number of these bodies varies enormously. In some tumors almost every alveolus contains several of them, in others they are wholly absent. They have no specific staining reactions. Plimmer has devised a special stain to demonstrate them, but they may be shown by the ordinary stain of hæmatoxylin and eosin. They are certainly the most distinctive of all bodies included in the protoplasm, but there is nothing in their size, form, structure, or staining reactions which should lead us to consider them living parasites. The other objects included in the protoplasm may be divided into two classes. One class is composed of bodies generally round, sometimes single, sometimes in groups, always homogeneous and closely invested by the protoplasm. They stain in various ways, and many of them have a special affinity for certain dyes and in this way may be sharply differentiated from the protoplasm. Russel described certain of these which are sharply stained with fuchsin, and which have since been generally known as Russel fuchsin bodies, and he regarded them as probable parasites. Bodies similar to these may be found in a large number of pathological conditions, and they are obviously nothing but various forms of degeneration of the protoplasm. The third group of bodies are the most variable of all. They always lie in vacuoles in the protoplasm. They are irregular in size, and careful study will show every variation between the most indefinite of these bodies and structures which may certainly be recognized as cells, and even the special variety of cells may be distinguished. The cells of carcinoma differ further from ordinary epithelial cells in their marked phagocytic properties. The included cells may be cells or portions of cells from the tumor itself, polynuclear leucocytes, or the lymphoid and plasma cells of the stroma. The last two groups of inclusions are easily explained; they are in no way peculiar to carcinomata or any of the tumors.

The various transformations which included cells may undergo can probably be better studied in the large cells of typhoid fever than elsewhere. They are also very numerous in the proliferating connective-tissue cells of granulation tissue. The bodies first described are more difficult of explanation and probably no single explanation of their origin can be given. I am convinced that many of them are due to degeneration of the nucleus. In a tumor which developed in a cicatrix after the operation, and in which they were very numerous, it was possible to see transitions in the nuclei leading to these bodies. The chromatin of the nucleus disappeared, the whole structure becoming homogeneous, and the nucleolus remaining as the central granule. They may also be referred to degeneration of segments of the nucleus which are occasionally thrown off and which represent the degenerative direct division. Borel believes that some of them are certainly to be referred to changes taking place around the centrosome, the radiate bodies being the spindle, and the granule in the middle the remains of the centrosome In the giant cells of a sarcoma I have seen degenerations of the numerous centrosomes which become swollen up and the spindle around them more definite, but none of these bodies were found. Whatever the explanation given, there is nothing in the present state of our knowledge which should lead us to regard them as parasites. The defenders of the parasitic theory have been able, in a small number of cases, to cultivate yeasts from carcinomata. They have inoculated animals with these cultures and in a very few instances, not more often than could be explained as a coincidence, epithelial tumors have resulted. Almost invariably the new formation of tissue which has resulted from the inoculation has been granulation tissue of a sort which would follow from the introduction of any injurious agent.

It would not be justifiable to deny the possibility that carcinoma may be due to a parasite, but no evidence of this has been adduced up to the present time. On the contrary, everything we know of the tumor speaks against this idea. If a parasite is the cause, it must be different from any form of parasite we know, and its relations to the tissue must be different. It would be difficult to assume that a parasite could infect the tissues at a certain point, giving to the cells certain properties which would be retained by all following generations of cells. Otherwise we must assume a symbiosis between cell and parasite, as the parasite must be present in all cells and be carried with the cell to produce a metastasis, for a metastasis cannot be due to a parasite alone.

When the carcinoma once starts the cells themselves act as parasites. In the removal of a carcinoma, if the operation is to be successful, all the parasitic cells must be removed. It is not sufficient to remove the primary tumor and the lymph glands connected with the tissue, but the tissue between the two, in which the lymph vessels run and which may contain straggling cells, must also be removed. It may be extremely difficult to do this, for the blocking of the glands by metastases and the occlusion of the ordinary lymph channels may bring other collateral channels into play. The frequency with which the tumor reappears in the cicatrix after operation may possibly often be due to infection of the incised part by the knife of the surgeon.

W. T. Councilman.

CARCINOMA. (CLINICAL.) See *Cancer.* (*Clinical.*)

CARCINOMA OF THE SKIN.—A uniform nomenclature of malignant growths of epithelial tissue is, even in the present state of our pathological knowledge, by no means employed by writers.

In a general way, however, carcinoma is used to designate all varieties of malignant growths of epithelium, including both the glandular and the surface varieties. The majority of writers use the term epithelioma when referring to primary cutaneous cancers.

Fabre and Domergue * make a clinical and pathological distinction between epitheliomata and carcinomata of the surface in the manner of growth (orientation) of the cells and the relationship of the cells to the basal layer of the epidermis.

In the present article carcinoma is employed as a comprehensive term embracing all the varieties which have their starting-point in the surface epidermis or its appendages.

SYMPTOMATOLOGY.—The primary forms which skin cancers assume depend to some extent on their seat and minute structure. We are unable, because of so many exceptions to this statement, to formulate any rule which will always associate a definite clinical type with a fixed histological structure.

The old division of carcinomata of the skin into (1) the superficial, flat, or discoid, (2) the deep-seated, nodular, or infiltrating, and (3) the papillary, is still largely employed as furnishing convenient terms for use in descriptions.

This classification is more or less imperfect, as the flat or discoid form may become deep-seated, the latter involving the skin secondarily as a superficial growth, while both are at times complicated by papillary outgrowths.

Unna † has attempted to reduce the majority of skin carcinomata to a few types according to the gross histological appearances or architecture of the growths. He obtains in this way three chief forms which he designates (1) the fungating, (2) the cylindrical, (3) the alveolar, each of which is further subdivided. A fourth or sub-form (carcinomatous lymphatic infarction secondarily affecting the skin after breast cancer and in metastases) is added to this classification.

The classification proposed by Unna is based chiefly on the histological structure of the growth, and in the fungating form the macroscopic appearance of the tumor is considered as well.

To one unfamiliar with the histological details of carcinoma of the skin the classification is too involved for practical purposes. A further reference will be made to it in describing the minute anatomy of these new growths.

To avoid confusion in the clinical picture of the malady certain primary types of more or less uniformity will be described, and then reference will be made to the forms which follow or develop on some pre-existing morbid condition of the skin or constitute the final stage of such affections, as xeroderma pigmentosum, Paget's disease, lupus vulgaris, syphilis, etc.

An important fact to be borne in mind is that carcinomata of the skin are not infrequently multiform in their manifestation and often have a relatively benign course.

Superficial Epithelioma.—One of the most frequent forms in which carcinoma of the skin begins is as a small, hard, pearly gray nodule generally found on the upper two-thirds of the face in individuals over forty years of age. These nodules are often multiple, may remain for years with little or no change, or even may disappear spontaneously. If they are removed during their primary stage before ulceration begins they show only a slight tendency to recur.

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* "Les Cancers Epithéliaux," Paris, 1898.

† Unna, "Histopathology of the Diseases of the Skin," p. 670.

After a time one or more of these small growths may slowly increase in size, the centre at the same time sinking in and eventually becoming fissured or excoriated as the result of scratching or other irritation. At this stage, the new growth consists of a superficial ulcer covered with crusts made up of blood and secretions from the affected surface, and surrounded by a hard, elevated, waxy looking margin (Fig. 1, Colored plate XXI.). The central ulceration may heal but is sure to recur, each time becoming somewhat larger, but seldom involving the deeper tissues; it has a red, granular base, secretes but little pus, and rarely causes pain. The floor and edges of the ulcer, consisting of soft friable tissue extending beneath the overlying epidermis, are easily removed by the curette. Instead of extending in a regular and progressive manner the ulceration may heal in the centre while continuing to spread at the margins, or one side may cicatrize, as a result of which gyrate and irregularly outlined ulcers with new foci may develop in the scar tissue (Fig. 1135). Such a carcinomatous ulcer may generally be differentiated from syphilitic or lupous ulceration by the presence of the elevated, waxy, or pearly gray margin.

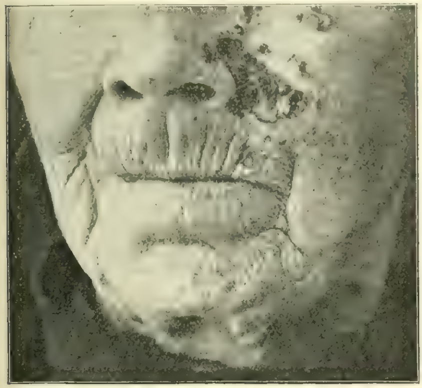

FIG. 1135. Superficial Epithelioma of the Face (Rodent Ulcer Type) of Fifteen Years' Duration. Showing scar tissue and peripheral ulceration.

The progress of the affection is excessively slow, lasting ten, twenty, or even forty years before the patient dies from this or some other malady. It may eventually, however, invade the orbit, destroy the greater part of the skin of the face, the malar bones, the upper jaw, and penetrate the skull, causing the death of the patient from hemorrhage, exhaustion, or the involvement of vital organs. Fungating tumors reaching a considerable size may spring up from these ulcerating surfaces.

This variety of malignant growth, which has its primary seat near the eye, beginning as a minute, pearly gray nodule and spreading in a slow but progressive manner, is the so-called rodent or Jacob's ulcer, regarding the nature of which there has been so much discussion and divergence of opinion. It seldom or never invades the lymph nodes, and does not produce metastases or give rise to cachexia. It was looked upon by the older writers, such as Brodie and Paget, as a disease distinct from carcinoma and some modern authors even now deny its carcinomatous nature. Probably several varieties of superficial skin carcinoma during their course may assume the appearances described, so that the name, if retained, should be used in its clinical significance rather than to indicate a distinct species of epithelial new growth. Unna, on the other hand, opposes the view that every flat, superficial, carcinomatous ulcer should be called rodent ulcer. He believes that the latter affection has certain definite clinical as well as histological features which are characteristic, and that it should not be confused with other varieties of carcinoma.

In addition to the early lesion in the form described, epitheliomata about the face may begin as brownish-red tubercles, hemispherical in outline, quite smooth, and of medium consistence. When first observed they are smaller than a split pea, slightly elevated, and may reach the diameter of half an inch before breaking down. These small nodules are readily scraped away with the dermal curette and apparently show little tendency to recur. They are seen about the ala of the nose, the eyelid, and the forehead. Sections of such growths under the microscope are found to contain proliferating bands, tubular processes, and acinous-shaped masses of small epithelial cells which correspond to those in the basal layer of the epidermis. These proliferating tracts and masses of cells are surrounded by a layer of columnar cells which represents the basal layer and probably limits their rapid growth. They are enclosed in a loose meshwork of connective tissue which is generally poorly developed or may be almost absent.

If undisturbed these nodules grow slowly for a number of years, then, under the stimulus of some irritant, increase more rapidly in size, finally resulting in open ulcers.

Disseminated Epithelioma of the "Sebaceous Type."—Multiple epitheliomata which are met with especially about the face, sometimes on the hands and trunk, are usually preceded by certain definite changes in the skin to which the name "senile keratosis" has been applied.

The skin at first becomes somewhat rough, and is covered by scales adherent to the follicular openings. Later, scabby concretions of a dirty yellowish-brown color form, and beneath them is found a warty condition which bleeds readily on slight irritation. Small cup-shaped depressions are subsequently noted beneath the thickened and altered horny layer; these coalesce and give rise to open epitheliomatous ulcers having hard, elevated edges and bases. A number of years may elapse from the time when the first changes in the skin appear before a malignant development takes place.

The same patient is frequently affected with several epitheliomatous ulcers in different stages of growth as well as with encrusted papillomatous areas which have not yet undergone the malignant change. The severer cases occur among those patients who are exposed to vicissitudes of weather and to the heat of the sun and in whom the earlier alterations in the skin which predispose to the condition are overlooked or neglected.

Other senile changes in the skin, as pigment deposits, papillomata, alterations in the blood-vessels, atrophy of the subcutaneous connective tissue, predispose to malignant new growths. These changes are allied to those which occur in the young in a more aggravated form, constituting the disease known as xeroderma pigmentosum, which, as a rule, terminates in the development of one or more malignant tumors. They are also met with in the condition known as sailors' skin, which Unna * has observed and investigated. The changes which take place on the exposed portions of the face and hands are at first a cyanotic redness, followed by pigment deposits and leucodermatous spots. Localized thickening of the horny layer of the epidermis next occurs, and this, at certain spots, assumes a warty character, to be followed by papillary and ulcerating epitheliomata. While in their early stages these ulcers pursue an indolent course, and involve only the superficial tissues; at a later date they are more rapidly destructive than the rodent ulcers.

In Paget's disease of the nipple a superficial, moist, crusted, slightly scaling dermatitis may exist for a number of years as a precancerous condition. Healing cannot be brought about by the ordinary applications and eventually a superficial or deep-seated carcinoma appears in or beneath the chronic dermatitis. It is usually of the alveolar type, and more frequently begins in the lactiferous ducts than in the epidermis itself. Swelling of the lymph nodes is met with in the later stages of the disease.

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* Unna, "Histopathology of Diseases of the Skin," p. 719.

Multiple epitheliomata at times develop on old patches of psoriasis. The prolonged use of arsenic in this and other chronic skin diseases is at times followed by patches of keratosis and horn-like lesions especially on the palms of the hands and soles of the feet, beneath which cancerous ulceration begins. These malignant changes are usually multiple, and in fifty per cent. of the cases recorded they developed before the age of forty. Among arsenic miners carcinoma, beginning as arsenic warts on the fingers, has not infrequently been observed.

Hutchinson has repeatedly called attention to the etiological relationship supposed to exist between the internal use of arsenic and the development, on the palms and soles, of keratoses which terminate in carcinoma; and lately Hartzell[*] has reviewed the subject, giving at the same time the report of a case of his own which showed this sequence of development.

Chimney Sweeps' Cancer of the Scrotum.—This variety of cancer, which at one time was often met with in England, has become less frequent since the enforcement of laws forbidding sweeps to ascend flues. The retention of soot in the folds of the scrotum gives rise to a chronic dermatitis and warty outgrowths. After a time one or more of these warts ulcerate and eventually involve the superficial as well as the deep tissues. The inguinal lymph nodes after a time become implicated.

Tar and Paraffin Cancer.—Volkmann[†] first called attention to the occurrence of cancer of the scrotum and forearms in workers in coal tar and paraffin. The antecedent changes in the skin are similar to those met with in chimney-sweeps' cancer. The follicular openings are occluded, the skin becomes dry, thickened, and the seat of warty growths which subsequently become malignant.

It is not improbable, as has been suggested by Esmarch and Langenbeck, that tobacco, soot, tar and paraffin are closely allied in their power to stimulate epithelial growth. Abnormal cell division has been experimentally produced by treating the dividing cells with poisons and chemical agents, thus rendering more probable the relationship which is believed to exist between the long-continued use of arsenic and the development of cancer, and at the same time favoring the view that this variety of new growth may owe its origin to the stimulation furnished by such chemical agents as tobacco, tar, etc.

Chronic affections of the derma, as lupus, syphilis, etc., seem to favor the development of carcinoma by lessening or removing the normal barrier which separates the epithelium from the connective tissue. At the same time a constant irritation is exerted on the epithelial layer which causes it to undergo hypertrophy and ultimately may lead to its becoming the seat of a malignant growth.

Carcinomata develop from active lupus or from its scar tissue so frequently as to indicate more than an accidental relationship. They are apt to assume fungating forms, to prove rebellious to treatment, and to pursue a more rapid course than when they develop independently of such a connection. They have also not infrequently been observed to start from late syphilitic lesions of the skin, in which case there is danger that they may be overlooked because the original disease often obscures their characteristic features.

Syphilis of the tongue is one of the most frequent precancerous affections of this organ. Late syphilitic neoplasms, interstitial glossitis, and leucokeratosis may be followed by rapidly growing carcinomata. Indifferent scar tissue of the skin, when exposed to long-continued irritations, forms a favorable soil for the development of a malignant tumor. The course of such growths is less rapid than when they start from the scar-tissue of lupus. In the latter case there is nearly always more or less active tuberculous disease and thus less resistance is offered to the epithelial ingrowths.

Papillary Carcinoma.—Papillomatous tumors bear much the same relationship to epitheliomata as the adenomata do to glandular carcinomata. They consist of a rapid growth of the cells comprising the Malpighian layer with a consecutive hypertrophy of the papillæ beneath. As long as the basement membrane remains unimpaired the invasion of the underlying tissues by the growing epithelium is prevented.

Papillary growths frequently spring up from the base and periphery of carcinomatous ulcers, especially when a mucous membrane is involved, and obscure by their rapid development the features of the primary tumor. The scalp is sometimes the seat of these secondary growths (Fig. 3, colored plate XXI.), which assume a cauliflower-like appearance and convey the impression of a more malignant tumor than is warranted by their clinical course. These outgrowths are usually broader at their surface than where they are attached to the morbid growth, and they spread over the healthy skin in a radiating manner for a considerable distance.

The seats of predilection of a primary papillary carcinoma are the glans penis and the lips. An absence of a firm epithelial covering facilitates the surface growth of the prickle layer (Unna). The horny layer may in the early stages be thickened and firmly attached, but, later, cornification becomes abnormal, and the enlarged papilla with the rapidly growing and unprotected prickle cells, bleeds readily on slight irritation. Surface infection takes place with consecutive necrosis of the superficial layer of cells. As long as the epithelial proliferation is superficial, these growths are easily removed. When the deeper tissues are invaded they spread at times with alarming rapidity owing to their active cell-growth. Sooner or later ulceration takes place and the early features of the affection may be lost. In Fig. 2 of the accompanying colored plate a carcinomatous ulcer is depicted which began as a wart, but at the time when the picture was taken the papillomatous growth had entirely disappeared.

These carcinomata differ from the growths of the rodent-ulcer type in their tendency to form horny or hyaline pearls as well as in their more rapid and malignant course.

Cutaneous horns are modified papillomatous tumors in which cornification is greatly exaggerated. Epitheliomata sometimes start from the base of such growths and terminate in open ulcers, which pursue the ordinary course of the malignant new growth.

Carcinomata from Nævi.—Pigmented and non-pigmented moles often present the structure of an alveolar carcinoma, and while the great majority of such congenital malformations retain their benign character, they occasionally give rise to growths of great malignancy.

Unna[*] and Gilchrist[†] have shown that these nævi are caused by the snaring off of epithelium from the surface epidermis in embryonic life or in early youth. Malignant tumors arising from such a matrix later in life are therefore carcinomata and not sarcomata, as has been so long held by the majority of pathologists.

It has not been clearly determined that all malignant melanotic tumors are carcinomata, but if certain of these are of mesodermic origin it is impossible to differentiate the two classes clinically. These melanotic tumors may develop on any part of the body, generally on the extremities or genitals. They are at first bluish-black or slate-colored growths assuming wart-like or fungous forms.

Secondary tumors may develop in the vicinity of the parent growth, and, spreading along the lymphatic vessels, give rise to large nodular growths in the lymph nodes. Metastatic tumors rapidly form in the viscera, and cachexia soon appears, followed by a fatal termination, sometimes within a few months after the appearance of the primary tumor.

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[*] "Epithelioma as a Sequel of Psoriasis and the Probability of its Arsenical Origin." The Amer. Jour. Med. Sci., vol. cxviii., 1899, p. 265.

[†] Beiträge zur Chirurgie, 1875, p. 380.

[*] "Histopathology of Diseases of the Skin," p. 745.

[†] Journ. of Cutan. and Genito-Urinary Dis., vol. xvii., p. 117.

EXPLANATION OF PLATE XXI.

EXPLANATION OF PLATE XXI.

[illegible]

[illegible] of the epidermis or in the outer root-sheath of the hairs [illegible]

[illegible] ch rapidly spread after the application of some caustic. [illegible] ere enlarged. The microscope showed the tumor to be a [illegible]

[illegible] its margin resting on the healthy skin. The body of the [illegible]

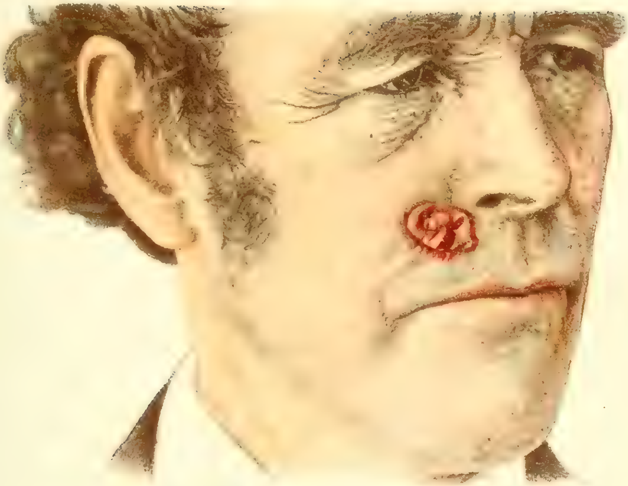

FIG. 1. EARLY STAGE OF RODENT ULCER OF THE FACE

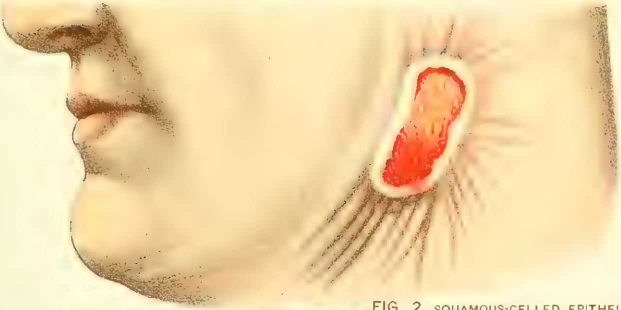

FIG. 2 SQUAMOUS-CELLED EPITHELIOMA OF THE SKIN.

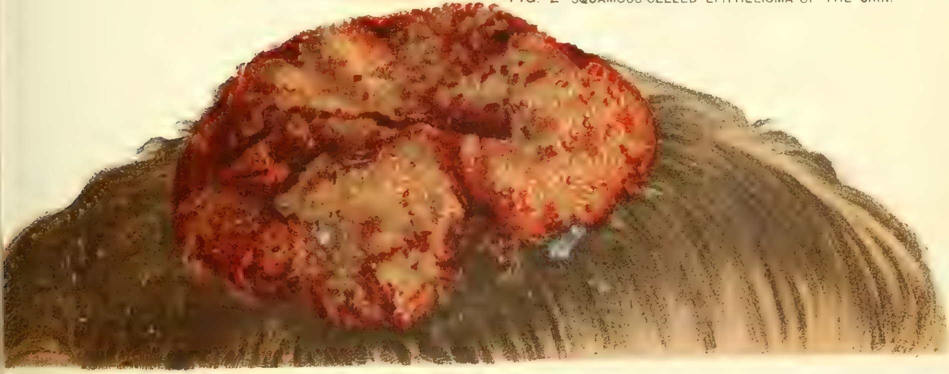

FIG. 3. PAPILLARY OUTGROWTH WHICH DEVELOPED ON EPITHELIOMA OF THE SCALP.

CARCINOMA OF THE SKIN.

Deep-Seated or Nodular Carcinoma.—The great majority of cutaneous cancers conform to one or more of the types which have been described and are in their early stages more or less superficial. Many preserve such a location during their entire evolution, the new growth ulcerating as soon as it develops. Others may early tend to involve the deeper tissues, giving rise to distinct indurations or veritable tumors which invade the muscles or bones. The deep-seated or nodular carcinoma is, therefore, usually secondary to a surface ulceration, but it may occur near the cicatrices of former operations for malignant disease, a group of cells in the subcutaneous tissue acting as a focus for the relapsing growth.

Metastatic cancers of the skin from visceral or breast carcinoma are usually first detected as small subcutaneous nodules which, in exceptional cases, may enlarge, assume an irregularly rounded shape, and become firmly attached to the underlying tissues.

Certain carcinomata of the surface epithelium, more especially of the tongue and lip, show an early tendency to deep infiltration and are apt to pursue a more malignant course from the beginning. The only plausible explanation that has been given as to why these growths tend to involve the deeper structures, is, that the downward growth of the epithelium can take place more readily in these localities where the tissues are rather succulent. Fabre-Domergue, however, attributes their more malignant course to the character of the new cell growth, which is favored by the absence or non-continuity of the basal layer about the masses of growing epithelium. In carcinoma of the tongue there is little or no disposition on the part of the epithelial cells to form concentric globes containing horny or hyaline masses, but the constituent cells grow, multiply, and end their existence independently and simultaneously. There is, consequently, in these tumors of the tongue an absence of those histological features which limit cell growth in many of the surface epitheliomata.

Deep-seated epitheliomata, when primary, may begin as single or multiple pea-sized nodules of a whitish or purplish color. They increase slowly in size, become more irregular in outline, and form adhesions to the overlying skin. Eventually there is produced a firm, projecting tumor, which may reach the size of a hen's egg, over which dilated blood-vessels are prominently seen. Ulceration subsequently takes place, leading to the formation of cavities which increase in a progressive manner as the infiltration spreads and breaking down of the tissues occurs.

Papillomatous growths sometimes spring up from the base or walls of the ulcerating surface, the edges of which may contain waxy nodules like those seen in the superficial varieties. The lymph nodes may be involved at a comparatively early period and metastases may develop in the internal organs; then follow marasmus and death.

Under the name of tuberose carcinoma cases of this kind have been described in which multiple, deep-seated tumors developed simultaneously and broke down into ulcers which soon led to the patient's death.

Carcinomatous Lymphatic Infarction.—This is the name given by Unna to a sub-form of cancer of the skin. It is generally described as lenticular carcinoma. It is met with, in the great majority of cases, in the skin covering the female breast as a development secondary to mammary carcinoma; it may also develop in the cicatrix following operation for cancer of the gland. Epithelial cells from the primary growth are conveyed by the lymph vessels and give rise to the formation of small white or pinkish papules from the size of a small shot to that of a pea. Infiltrated patches at times result from the confluence of numerous primary nodules which may or may not undergo ulceration.

When the lymphatic infection is active and extensive the entire cutaneous surface over the front and back of the chest may be involved, the process even extending to the skin of the abdomen and arms. In the later stages the skin becomes hard and leathery in consistence from the growth and contraction of the connective tissue, producing the condition known as *cancer en cuirasse*.

The constriction produced by the new growth may be sufficient to interfere with respiration or may give rise to œdema of the arm from interference with the lymph circulation. A fatal result may follow within a few months after such a development occurs, but in certain cases general infection is delayed for a number of years.

Carcinoma of the Sweat Glands.—The most divergent opinions exist as to the rôle played by the sweat glands in tumor production. Certain pathologists at various times have attempted to show that many small-celled epitheliomata, in which the cells grow in tubular processes, have such an origin. It has, however, been clearly demonstrated that neither the shape, size, nor arrangement of the cells furnishes sufficient criteria on which to base the diagnosis of sweat-gland cancer. Darier * has reported a peculiar case that occurred in the service of Besnier, in which multiple, deep-seated, and painful tumors developed with great rapidity on the trunk of a man aged seventy-one. Darier's examination showed that each tumor started with a proliferation of the sweat-gland epithelium, which filled the lumen of the canal, broke through the membrana propria, and infiltrated the connective tissue. He gave to his case the name "diffuse multiple epithelioma of the sudoriparous glands," and believed it to be unique in the number, the rapid evolution, and the structure of the tumors. The author was able to find but two analogous cases in medical literature, one of which was reported by Malherbe, the other by Creighton. In the latter case a dog was the subject of the affection. In Darier's case death resulted within a few months after the beginning of the affection.

The author of the present article some years ago examined a tumor which had been removed by Dr Bronson from the anterior surface of the leg of a man thirty-five years old, and which proved microscopically to be a carcinoma originating in the coil gland. The growth in question was composed of distinct lobules, separated by the ingrowth of connective tissue; it was soft to the feel, about half the size of a small egg, and defined from the surrounding tissue without being distinctly encapsulated. It extended about one inch below the skin, and measured an inch and a half in its long diameter. An open ulcer, somewhat larger than a dime, was present over the tumor. The cancerous nature of the new growth was not suspected prior to the microscopic examination.

Neither the duration of the tumor nor its onset as a surface or deep affection was noted.

Carcinoma of the Lip.—Cancer of the lip, by reason of its frequency, malignant course, and the importance of an early diagnosis, demands a separate consideration. Its seat of predilection is the lower lip, at the junction of the skin and mucous membrane near the median line. It may occur near the angle of the mouth. The development of a tumor on the upper lip has been noted in one or two instances. In these cases contact with the primary growth on the lower lip may have served as a cause. Cancers of the upper lip, as a rule, occur at some distance from the vermilion border and are usually of the rodent ulcer or superficial type of growth. When the mucous membrane is involved by the extension of such a tumor of the upper lip its clinical course differs from that of the typical cancer of the lower lip. It does not penetrate deeply nor infect the lymph nodes as in the latter case.

A number of primary changes in the surface epithelium may precede ulceration or tumor formation. Hyperkeratosis over a limited area, followed by a fissure and later by ulceration, is often observed. The ulcer is irregular in outline and surrounded by thickened and elevated margins (Fig. 1136). The base of the ulcer becomes indurated and the infiltration gradually extends to the deepest issues.

In another case the epithelium may become eroded instead of thickened and covered by closely approximated granulations which enlarge until they assume a warty character. This papillomatous growth may spread laterally until almost the entire lip is covered with granulations before deep extension takes place. Instead of the ragged ulcer which is portrayed in Fig. 1137, a shallow, oval and regularly outlined loss of tissue may constitute an early form of lip cancer (Fig. 1136). (Figs. 1136 and 1137 are reproduced here by the kind permission of the *New York Medical Journal.*)

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* "Contributions à l'étude de l'épithéliome des glands sudoripares." Arch. de méd. expérimentale et d'anat. pathol., 1889, pp. 115, 267.

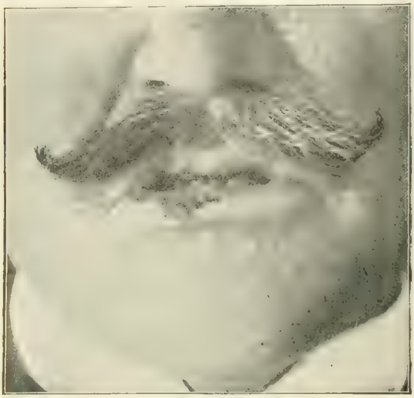

FIG. 1136.—An Early Stage of Cancer of the Lip. Showing superficial ulceration.

Changes in the epidermis may be overlooked and the patient's attention may be first directed to a hard growth below the surface. This soon ulcerates, leaving a cavity surrounded by hard walls and base from which the degenerated epithelial cells forming the centre of the epithelial "pearls" may be squeezed out as comedo-like bodies.

In neglected cases the infiltration and ulceration involve the entire lower lip and the floor of the mouth; the teeth become loosened and all the adjacent tissues are destroyed. The submaxillary and submental lymph nodes are involved, as a rule, before such extensive tissue destruction occurs. The average duration of life in untreated cases is from three to five years, death taking place from sepsis or metastasis.

Cancer of the lower lip occurs in about fifty per cent. of surface epitheliomata. The male sex furnishes an overwhelming percentage of all cases, variously estimated at from eight to one to twenty to one. Statistics show that the large majority of those so afflicted are addicted to the use of tobacco, and of the few cases met with in women three-quarters were smokers.

Diagnosis.—The initial lesion of syphilis is often mistaken for cancer of the lip. Chancres of the lip are usually protuberant with an eroded or encrusted surface; they develop rapidly and very early involve the lymph nodes. The initial sore of syphilis is more likely to be met with in young adults, while epithelioma is a disease of later life. Numerous exceptions to these rules, however, are found.

Late ulcerating syphilides of the lip have also been mistaken for cancer, but these neoplasms of syphilis are usually multiple, rapidly break down or undergo absorption with atrophy, and lack the hard base which is always present in cancer.

In a doubtful case appeal should be made to the microscope.

Prognosis.—The course of carcinoma of the lip is much more rapidly fatal than is that of the flat variety of epithelioma of the skin. An early and radical excision by the knife is the only method of treatment which promises subsequent immunity to the patient. If the operation is performed while the affection is superficial the outlook is not unfavorable. Even in such cases early operations sometimes fail to prevent general infection.

PATHOLOGY AND MORBID ANATOMY.—Carcinomata of the skin in the great majority of cases start from the surface epithelium or the epithelium lining the hair follicles. The sebaceous and sweat glands only exceptionally are primarily implicated.

It is not possible in all instances to associate a definite clinical type with a fixed histological structure.

Unna's plan of classification, which reduces the majority of skin cancers to a few types according to the architecture of the growths, involves the mutual relationship of the growing epithelium to the resisting connective tissue. A proper presentation of his views would involve an extended discussion, which is scarcely in place in this connection. A distinction of some clinical as well as pathological importance is that which separates these new growths of epithelium into two groups, in one of which the cells are chiefly of the squamous variety, while in the other they are of the small or columnar type. As a rule the squamous-celled epithelioma is found about the muco-cutaneous orifices, more readily involves the lymph nodes, and is more malignant than the small-celled variety of the disease. The difference in malignancy between these two types of growth is perhaps not so decided as it was at one time believed to be.

Squamous-celled epitheliomata are seen at a distance from the orifices. They may persist for a period of ten years without invading the lymph nodes, and then exceptionally the rodent-ulcer type of growth is met with in which the communicating lymph nodes are involved.

We are as yet ignorant of the factors which render rodent ulcer a relatively benign affection and the squamous-celled epithelioma a more malignant growth. The superficial seat of rodent ulcer and the early occurrence of ulceration are supposed by some writers to prevent the absorption of the cells by the lymph vessels. The resisting power of the connective tissue, which in rodent ulcer early assumes a structure like that met with in scirrhous cancer, is looked upon by Unna as an important factor in determining the clinical course of the affection.

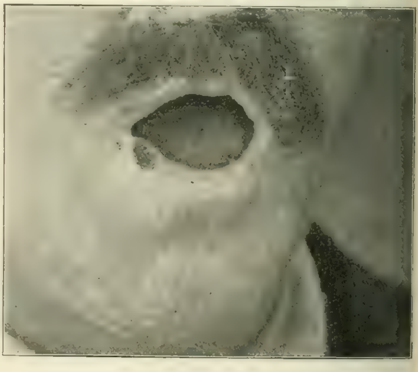

FIG. 1137.—Early Form of Cancer of the Lip. A shallow concave ulcer near angle of the mouth.

Although the new growth of epithelium which we see in rodent ulcer is always made up of small cells which correspond to those in the basal layer of the epidermis or the outer root sheath of the hair follicle, it is possible that there are a number of other clinical varieties of small-celled skin cancers which are not identical, at least clinically, with rodent ulcer.

Carcinomata of the surface epithelium, according to the classification of Fabre-Domergue, may develop in the direction of the adult type of cell, giving rise to cornification of individual cells or to rudimentary epidermic "globes," between which type and the true epitheliomata there are many transitional forms. They may furthermore assume the embryonic type of growth and simulate so closely glandular carcinomata that it is not always possible to differentiate them by their histological structure.

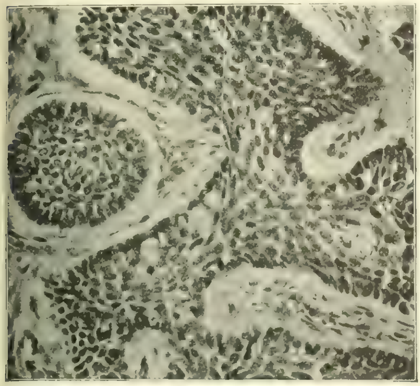

FIG. 1138.—From a Rodent Ulcer of the Face. Showing cylindrical processes of small epithelial cells surrounded by a basal layer. (Spencer one-quarter inch, projection ocular 2.)

In carcinomata of the adult there are, beside the embryonic type of cell, the same tendency to general cell activity throughout the growth, a non-continuity or absence of the basal layer, and consequently in both the same tendency to deep infiltration and general infection.

The clinical gravity of the tumor depends, therefore, on its structure rather than on its location.

The embryonic epithelioma (Fabre-Domergue), the tubular epithelioma of Cornil and Ranvier, and the small- or columnar-celled epithelioma correspond in all essential points and are identical in structure with rodent ulcer in its earlier stages. The tumor originates from the lowermost layer of the rete Malpighii or from the outer root sheath and preserves with rare exceptions its embryonic cell structure throughout its entire course. The new growth of epithelium develops in the form of cylindrical processes throughout the lymph spaces of the derma (Fig. 1138). It is preceded by the appearance of a dense mass of mononucleated leucocytes (plasma cells, Unna). The connective tissue between the masses of growing epithelium becomes thickened and sclerotic and probably limits the down growth of the cylindrical processes, which may later assume elongated shapes owing to the greater resistance which they encounter.

The tubular processes of young epithelium are surrounded, in the earlier stages of the process, by a layer of cells which correspond to the basal cells of the epidermis (Fig. 1138). As the affection extends it is more difficult to identify this layer and it finally disappears. The loss of this protective layer is probably one reason for the more rapid extension of the growth in its later stages.

No good reason has as yet been advanced why the lymph nodes are not involved in rodent ulcer unless it is owing to the greater resistance interposed by the connective tissue. That they may exceptionally become infected was shown in a case which recently came under the observation of the writer. A patient, sixty years old, presented a typical rodent ulcer, of ten years' duration, on the side of the nose, extending to the inner canthus. He had at the same time, behind the ear, an epithelioma with identical clinical features. The lymph node over the mastoid process was enlarged and after excision was found to be invaded by typical cylindrical processes of epithelium which could not be distinguished from those in the derma.

The exceptional situation of the epithelioma in this case, at a point where the integument is thin and where the growth was subjected to pressure against the underlying bone, was probably the factor which determined the invasion of the lymph node in the immediate proximity.

Sweat-Gland Cancer.—The case of sweat-gland cancer which came under the observation of the writer and to which reference has been made, had the following histological structure: Under a low power the derma was found to be the seat of numerous bands, masses, and gland-like arrangements of small epithelial cells which extended from beneath the epidermis to the subcutaneous connective tissue. They differed in their arrangement from that met with in other varieties of skin cancer, and suggested to the observer an attempted reproduction of glandular tissue. Under a higher amplification a complicated network was seen; it was formed by the interlacement of bands of epithelial tissue enclosing cavities which were partially or completely filled with degenerated cells or with a homogeneous substance allied to colloid matter. Cyst-like cavities were found in other parts of the microscopic field. They were lined by a single layer of columnar epithelial cells, and presented a striking resemblance to overgrown sweat ducts.

Fig. 1139 represents a group of enlarged and proliferating sweat ducts cut transversely. The columnar shape and regular arrangement of the peripherally located cells are well shown. These cells are situated upon a basement membrane, and are an almost exact reproduction of those normally met with in the sweat glands, although here very much hypertrophied. The lumen of the tubules is completely filled by the growing and multiplying cells, and in places the basement membrane is penetrated and the surrounding connective tissue infected by them. The other anatomical structures of the skin were not implicated in the cancerous process, neither was there any evidence of a tendency to cell-nesting or the formation of epidermic "globes." The epithelial processes met with in the small-celled carcinoma of the

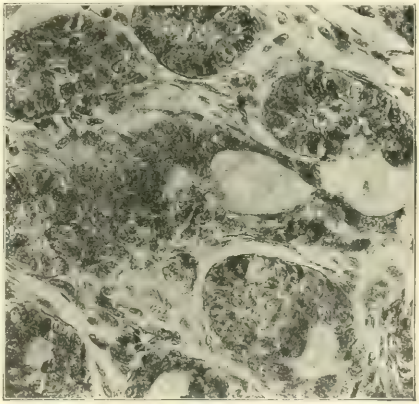

FIG. 1139.—From a Cancer of the Leg. Showing a group of enlarged and proliferating sweat ducts cut transversely. (Spencer one-quarter inch, projection ocular 4.)

skin, starting in the rete Malpighii, resemble to some extent the cell arrangements observed in the case under consideration. In the epidermic cancer, however, the cells are larger, and do not rest upon a distinct basement membrane, as in this case. Furthermore, the epithelial bands or tubules starting from the rete have no distinct calibre, and do not reproduce so perfectly the glandular structure.

Etiology.—The development of cancer of the skin is favored by a number of antecedent conditions to which reference has been made under Symptomatology. In a general way the statement is true that chronic irritation of slight intensity is one of the most potent factors which precede the malignant change in epithelial growths. The origin of highly malignant tumors from certain congenital moles has given some support to Cohnheim's theory of latent embryonic "remains." In xeroderma pigmentosum a congenital weakness of the skin is present which strongly predisposes to malignant growths. Heredity probably has some influence in favoring the evolution of some forms of malignant disease.

Inflammatory changes in the papillary region of the derma, by impairing the integrity of the basement membrane, favors the downward growth of epithelium. Atrophic changes in the connective tissue in advanced life exercise a similar influence.

The advocates of the parasitic origin of cancer consider the association of the malignant affection with pre-existing lesions as accidental. According to them the changes in syphilis and other chronic skin diseases merely furnish a favorable soil for the superadded infectious agent.

Cancer of the skin is more frequent after the age of forty, though no time of life is exempt. Kaposi has observed it a number of times between the ages of eight and eighteen. Rodent ulcer begins, as a rule, about the age of forty, but it may make little or no progress for several years.

Diagnosis.—Superficial cancer of the skin is frequently mistaken for late syphilitic infiltration and ulceration or for lupus. These late nodular and ulcerative syphilitic lesions are usually more rapid in their evolution and involution, are frequently multiple, and lack the characteristic elevated and waxy border which distinguishes malignant ulceration. When syphilitic ulcers or those of lupus are complicated with epithelioma the diagnosis is more difficult. Lupus generally develops early in life, pursues a chronic course, and spreads on the margins of the patch by brownish-red nodules deeply embedded in the skin. These nodules or tubercles are as characteristic of lupus as the waxy margin is of superficial epithelioma.

Tuberculosis verrucosa cutis might be mistaken for papillary cancer of the fingers or hands. Induration about the base of a wart or cutaneous horn should excite suspicion of a malignant change.

In case of doubtful diagnosis resort should always be made to the microscope.

Prognosis.—In superficial cancer of the skin the prognosis is more favorable than in any other form of the disease, as the progress is slow and the lymphatic system seldom implicated. If the growth is radically removed in its early stages there is little tendency to recur.

Cancers from moles are decidedly malignant, as they early involve the lymphatics and may soon be followed by a general metastasis. Papillary cancers are usually rapidly growing, and when they infiltrate the deeper parts, if not removed, lead to a fatal issue within from one to three years.

Rodent ulcer in its later stages almost invariably returns after removal, though preserving its local seat.

It is well to bear in mind that a superficial growth may become deep-seated and pursue a rapidly fatal course, as in the galloping or phagedenic epithelioma described by Besnier.

Treatment.—Early and complete extirpation with the knife is the only method of treatment that should be employed in cancer of the mucous membrane of the mouth, or of the lip.

On other parts of the body, as the neck, scrotum, etc., when the skin is freely movable and union by first intention can be secured, an excision offers the most rapid, painless, and satisfactory method of cure. If the operation is resorted to before the lymph nodes are invaded and if the incisions are made at a sufficient distance from the morbid growth, a cure may be looked for in the majority of cases.

Associated lymph nodes when invaded should be removed in as thorough a manner as possible.

Partial removal of cancer of the skin, even the most superficial, by the knife, curette, or caustics, accomplishes no good result and frequently stimulates these new growths to increased activity.

Superficial cancers of the skin are sometimes so situated that a cutting operation is followed by more deformity than after the employment of curettage and caustics. Many patients are so prejudiced against any cutting operation that they will endure the more prolonged and painful action of caustics rather than submit to the use of the knife. Under these circumstances the diseased tissue may be scraped away with the dermal curette and some suitable caustic applied to the resulting ulcer.

Numerous cures of cancer of the face have been obtained in this way by the writer, the caustics employed, as a rule, having been arsenic, in the form of Marsden's or Bougard's paste, or pure chloride of zinc. Arsenic is perhaps the best of all caustics as it is more certain in its action and presumably has a selective action on the morbid tissue. Marsden's paste is made by mixing two parts of arsenious acid with one part of powdered gum acacia and sufficient water to make the mixture of a firm consistence.

Robinson, who has devoted much time and consideration to the use of caustics in the treatment of cancer, prefers to vary the strength and duration of the application according to the cancer to be treated. He uses the paste in the strength recommended by Marsden and somewhat weaker, but never uses less than equal parts of arsenic and gum acacia. The paste is applied somewhat beyond the diseased area and is left on for from eight to twenty hours (Robinson). If the desired destruction of tissue is not obtained within the shorter limit a second but weaker application should at once be made until the necessary necrosis is accomplished.

The advantages claimed for the caustic treatment of cancer are the lesser degree of deformity which results and the greater certainty of reaching foci of diseased cells in the lymph vessels outside of the parent growth. It is, however, painful, and the separation of the resulting slough is somewhat slow.

Pain during the action of the caustic may be controlled by morphine, and the after-treatment should be conducted on the usual lines.

Before scraping away the morbid tissue as preliminary to the use of the caustic agent, the parts may be rendered anæsthetic by a spray of chloride of ethyl. If this is followed by the application of tampons saturated in a five or ten per cent. solution of cocaine the slight surgical procedure may be rendered absolutely painless.

Instead of employing destructive chemical caustics like arsenic and chloride of zinc the Paquelin or galvanocautery may be used to complete the treatment. The actual cautery is, however, not so certain to reach all the diseased cells as is the arsenical paste.

Patients who have been operated on for cancer should remain under observation for one or two years or longer, and the slightest recurrence should immediately be removed.

The internal use of arsenic for several months after the removal of malignant tumors has, perhaps, some influence in preventing or limiting recurrences.

John A. Fordyce.

CARDAMOM.—CARDAMOMUM. The fruit of *Elettaria repens* (Sonnerat) Baillou (fam. *Zingiberaceæ*). Since the seed is the only active part, the above definition should be so restricted. The cardamom plant is a tall, reed-like, perennial herb, from six to twelve feet high. The flowers and fruits are borne upon special short, scaly stems, partly prostrate among the bases of the leafy culms.

The plant is a native of Southern India, where also it has been long in cultivation. It has been introduced into other tropical countries. The cardamoms of commerce are mostly the product of cultivated plants, which are grown in the moist shade, either in clearings of the natural forests or in plantations of betel palms. The fruits are gathered before they are quite ripe. They are thoroughly washed, partly with soap and partly with a solution of a saponaceous fruit, and then bleached for some hours. They are frequently rubbed between the hands with a mixture of starch and buttermilk. They are ovoid or oblong, pointed, rounded-triangular, three-valved, and three-celled capsules. The husk, when dried, is of a pale yellowish-gray or brown, flexible, and tough. Those which have been starched have a white and almost chalky surface. The seeds, five or six in each cell, are irregularly compressed, brown, and spicy. The fruits of the best varieties are usually short, about once and a half or twice as long as broad (1 to 1.5 cm. = $\frac{4}{10}$ to $\frac{6}{10}$ in.), very plump and full. They are commercially called "shorts." Others, longer and more angular, are denominated "short-longs" and "longs." The larger and longer cardamoms are mostly the produce of other species of Elettaria, and are therefore unofficial. Their odor and taste are not so pleasant. In selecting cardamoms, the point of chief importance is to see that they are short, plump, and well-filled, as otherwise the proportion of husk is too great, and the strength is thus weakened through the diminution of the active portion. This difficulty can be avoided by specifying the amount of the seeds instead of the fruits. The seeds from unfilled fruits are themselves defective, however.

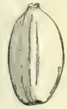

FIG. 1140.—Malabar Cardamom. (Natural size.)

Cardamoms are also distinguished, according to the countries or ports from which they are exported, as Malabar, Aleppo, Madras, etc. The former are the most esteemed.

The seeds contain about five per cent. of a pale yellow aromatic oil, of complex composition, which represents them in odor and taste. The ash of cardamom is rich in manganese. Cardamom is a typical aromatic, and is useful in all the conditions which call for articles of that class. As an agreeable flavor and appetizer, as a stimulant to digestion, and as a carminative in flatulence and in simple colic, it is sometimes, but not often, given alone. In combinations, as a pleasant and useful adjuvant and corrective, it is in more frequent use, acting favorably with cathartics, bitter tonics, stimulants, etc. But the principal use of cardamom is as a condiment or household flavor, for which purpose, especially on the continent of Europe and in the East, it is extensively employed. It is also used in flavoring liqueurs, and in curry-powder, etc. It is less irritating than the spices proper, and more so than anise and the milder carminatives. The dose of cardamom as an aromatic by itself would be from .5 to 1 gm. (gr. viij ad xv.). There is a ten-per-cent. official tincture which represents it completely. The compound tincture contains two per cent. each of cardamom and cinnammon, one of caraway, five of glycerin, and one-half per cent. of cochineal, in diluted alcohol, and is given in doses of 8 to 15 c.c. (2 to 4 fl. ʒ). It also enters into the aromatic powder and the aromatic fluid extract.

W. P. Bolles.

CARDAMOM, OIL OF.—This term is understood as applying to the volatile oil, and not to the ten per cent. of fixed oil which the seeds yield. It is yielded to the extent of five or six per cent. It is of a pale yellow color, highly aromatic, has a specific gravity of about .900 and a rotation of +13°. Its important constituent is *terpinene* ($C_{10}H_{16}$). Its properties are identical with those of cardamom. It is, however, chiefly used for flavoring, especially liqueurs.

Henry H. Rusby.

CARDIAC DEPRESSANTS AND CARDIAC STIMULANTS.—I. CARDIAC DEPRESSANTS.—The term cardiac depressant is applied to drugs which lessen the force and frequency of the heart's action and are employed for this purpose in therapeutics. Since all classes of vertebrates and many invertebrates are provided with a nervous mechanism (the cardio-inhibitory apparatus) through which such changes in the heart are brought about in the normal animal, we should expect to find that those drugs which experience has shown to have the power of reducing the heart's action would exert their influence through this mechanism. As a matter of fact, the two drugs which are most used for their depressing influence upon the heart, aconite and veratrum viride, do exert their influence through the cardio-inhibitory nerves. It is conceivable that the part affected by these drugs might be any point in this mechanism—the nerve centres in the medulla, the nerve fibres, which in the higher animals are contained in the vagi trunks, or that which is rather vaguely (since the exact anatomical elements are not well known) termed the endings of the nerves in the heart. As is well known, nerve fibres are, as a rule, less easily affected by drugs than are nerve cells or the terminations of nerve fibres; and no drug is known which is able to exert a special influence upon the cardio-inhibitory nerve fibres, although there are many which stimulate the nerve cells in which these fibres originate and also their terminations in the heart. There are, moreover, drugs which seem to increase simply the sensitiveness of the vagus terminations without actually stimulating them, or at least without stimulating them sufficiently to slow the heart; the increased sensitiveness may, however, cause them to respond to a slighter stimulus than usual or with greater energy to a normal stimulus.

Another class of drugs, of which tartar emetic is a good example, depress the action of the cardiac muscle directly and so have been used as cardiac depressants; but such drugs are not considered as safe as those which work through, so to speak, more physiological channels. In fact, the depression brought about by a direct action upon the cardiac muscle is often associated with the condition known as collapse.

For the sake of completeness it may be added that the heart's action may be depressed by drugs acting in ways other than those just mentioned. Thus, if a drug causes a great fall of blood pressure the heart may be imperfectly supplied with blood and beat very feebly and slowly. If the blood pressure be much increased by a drug causing contraction of the arterioles, the high blood pressure may act as a stimulus to the vagus centre and so depress the action of the heart. The vagus centre may be stimulated reflexly by drugs having a powerful local action; it may also be stimulated by the accumulation of carbon dioxide in the blood if some drug which interferes with the respiration has been given. Again, it is probable that there are drugs which can slow the heart by depressing the accelerator nerves. Since these nerves are in a condition of tonic activity, any interference with their activity would lead to a slower rate.

While the most typical cardiac depressants exert their influence through the cardio-inhibitory mechanism, their action upon the organism is not by any means confined to this apparatus. Not only may many other functions—as, for instance, those of the central nervous system, the respiration, secretion, etc.—be influenced, but other parts of the vascular mechanism (the vaso-motor centres and nerves, the blood-vessels, the accelerator nerves of the heart, the cardiac muscle, etc.) may undergo changes which exert a profound influence on their action as cardiac depressants. In fact, a drug may stimulate the vagus and thus slow the heart and at the same time stimulate the cardiac muscle and in this way antagonize the effect of the vagus; sometimes one and sometimes the other effect will predominate. The condition becomes much more complicated when the preparation used contains several active principles, each with its peculiar action. For this reason it is desirable to use simple preparations and to determine as accurately as possible all their effects; in this way reasons can sometimes be found for the failure of the drugs to produce the desired effects under certain circumstances.

The three drugs which have been used most extensively as cardiac depressants are aconite, veratrum viride, and tartar emetic.

Aconite.—The action of aconite as employed in medicine is almost identical with that of its chief alkaloid, aconitine. As most of the physiological experiments have been made with the alkaloid, its action will be considered first, and then the manner in which the other substances present in the ordinary preparations of aconite influence its action will be discussed.

Aconitine affects the circulation in three ways: it has a direct action upon the heart muscle, it stimulates the centre of the cardio-inhibitory nerves, and it influences the vaso-motor centre. With medicinal doses the second of these effects, the stimulation of the cardio-inhibitory nerves, is the most prominent and important and is the one desired in therapeutics.

When aconitine is administered to man or to one of the other mammals the first effect upon the circulation is usually a slight acceleration of the heart. This is usually attributed to a direct action upon the cardiac muscles, although it is not improbable that in some cases the effect may be brought about reflexly through the local irritant action which the drug is well known to have upon the terminations of sensory nerves. This slight acceleration may be accompanied by a small increase in arterial pressure. The acceleration of the heart, which with mammals is never marked and does not always occur, is followed by a remarkable slowing and weakening of the heart beat. In man a pulse rate of 36 to 40 not uncommonly follows a moderate dose of aconite. In cases of poisoning a still slower rate is occasionally seen; it is said to have been reduced to 10 per minute in one case. At the same time the pulse is much weakened. Sudden exertion at this stage may lead to a very rapid, irregular heart action and fatal syncope has occurred. Achscharumow (*Archiv für Anat. und Physiol.*, 1866, p. 255) showed that this slowing of the heart is due almost entirely to a powerful stimulation of the centre of the cardio-inhibitory nerves in the medulla oblongata. Section of the vagi prevents the slowing in nearly every case. At times, however, there seems to be a slight stimulation of the peripheral endings of the vagi, for some slowing may be observed when the drug is administered after section of the vagi; this slowing is abolished by atropine. This action upon the vagus terminals is of very slight importance in comparison with that upon the medullary centres; in fact, there is probably no drug which stimulates these centres as powerfully as does aconitine and has at the same time so little action, in small doses, upon other parts of the vascular mechanism. The amount of blood expelled by the heart under the influence of aconitine is much reduced and the blood pressure falls markedly. Some of the general symptoms of aconite poisoning are attributed to this fall of blood pressure. Thus there is a marked lowering of the body temperature, and this is usually ascribed to the depression of the circulation which leads to lessened oxidation and to an increased loss of heat from the surface of the body. Experiments of Brunton and Cash, however, indicate that there is also some action upon the nerve centres regulating the temperature of the body. The convulsions which frequently occur in cases of severe poisoning by aconite have been ascribed by some to the low blood pressure. While it is very probable that the latter is one factor in causing the convulsions, these seem to be due to a greater degree to a direct action upon some of the nerve centres, for convulsions occur in animals in which the fall of blood pressure is prevented by paralyzing the vagi with atropine. Moreover, there is ample evidence that several other parts of the medulla oblongata—the cardio-inhibitory, the vaso-motor, and the vomiting centres—are stimulated by aconite, and it is very probable that the nerve cells causing convulsions are similarly stimulated. The severe dyspnœa which is one of the first symptoms of aconite poisoning seems to be dependent to some extent upon the low blood pressure, for von Anrep (*Archiv für Anat. und Physiol.*, 1880, Supple. Bd., p. 180) found that if the blood pressure was raised by compressing the abdominal aorta the first symptoms of dyspnœa disappeared. Later there is a direct action upon the respiratory centre. The great muscular weakness so often observed seems to be due to anæmia of the spinal cord.

The details of the action of aconitine upon the mammalian heart have been recently studied by Matthews (*Journal of Experimental Medicine*, ii., p. 593) and Cash and Dunstan (Phil. Trans. of Roy. Soc., London, cxc., p. 248). By the use of a modified form of the Roy-Adami myocardiograph (an instrument by which the rate and force of the contraction of the cardiac muscle can be recorded) Matthews found that during the above, or first, stage of its action aconitine causes the following changes: the diastolic pauses of the ventricle are prolonged, the systolic contractions are weakened, while the relaxations of the ventricle are little changed or are a little increased. The relaxations of the auricle are little affected, but the diastolic pauses are much longer than in the ventricle. The auricular systolic contractions are greatly weakened and in some experiments are entirely suppressed, the auricle remaining in diastole; in such cases the ventricle assumes a slow, spontaneous rhythm. If the drug be administered in small doses, the rhythm can be reduced to one-half or to one-third of its original rate and the blood pressure lowered to a corresponding degree.

If the administration of aconitine be continued the heart beat becomes irregular and extremely rapid. Sometimes this effect is the first one seen in man, even after a moderate dose of the drug; it would seem that in such cases the cardio-inhibitory centre is not very irritable. The cause of this acceleration is frequently said to be the paralysis of the vagus terminations, but direct stimulation of the cardiac muscle seems to be a much more important factor. In fact, the effect of aconitine upon the peripheral endings of the vagi in the later stages of the intoxication has been a matter of considerable dispute. Some writers state that these structures are paralyzed, others that they remain intact, while a third group state that they may seem paralyzed at one instant and not at the next. Matthews has observed that sometimes stimulation of the vagus in the later stages of poisoning causes a change in the form of the contraction but no diminution in the rate. The explanation of the above results is probably that while the irritability of the vagus terminations is depressed that of the heart muscle is greatly increased so that inhibition is much more difficult. One reason why stimulation of the vagi causes slowing of the ventricle at one instant and not at the next may be found in the varying irritability of the muscle fibres connecting auricle and ventricle; these may be in a condition to transmit impulses from the auricle to the ventricle at one time but not at another.

Simultaneously with this acceleration, and often preceding it, there appear marked irregularities in the rhythm of the heart. These irregularities affect both the strength and the rate of the heart beat; they will be discussed somewhat fully here as similar irregularities occur after poisonous doses of many of the drugs acting upon the heart. At first, certain ventricular beats seem "missed"; when the number of such beats increases, the rate may seem but half as fast as before; but closer examination usually shows that there is an alternation of large and small beats and that only the former are distinctly recorded. The blood pressure falls during these imperfect systoles. This period of alternate large and small beats may be followed by a very rapid but regular rhythm during which the extent of the contractions is very limited. The auricle departs but little from the position of diastole and the ventricle from that of systole. Then periods of rapid beats may alternate with periods of slow beats. So far the auriculo-ventricular rhythm may have remained unaltered, each beat of the auricle being followed by one of the ventricle; but this rhythm is soon disturbed and contractions of the ventricle may occur independently of the auricle. The ventricular beat may dissociate itself entirely from that of the auricle and the two chambers beat independently of each other. At the same time there seems to be an effort on the part of the heart to maintain a simple ratio between the beats of the auricle and the ventricle; frequently this ratio is two to one or one to two—*i.e.*, the ventricle beats one-half or twice as fast as the auricle. Sometimes, when no such simple ratio exists, if one chamber becomes accelerated the other may become slowed until such a ratio is established. Many varieties of pulse may develop during this stage; but they may at any time yield to a regular one for a brief period, and stimulation of the vagi or accelerators will usually bring about the same result. The chief cause of this irregularity seems to be an increase of the irritability of the cardiac muscle which enables the ventricle to beat independently of the impulses received from the auricle. Two rhythms (one ventricular, the other auricular) are thus established, and they may interfere with each other. The extent of this interference is determined by the condition of the muscle fibres connecting auricle and ventricle and which transmit the impulses from one chamber to the other. As the intoxication continues the irritability of the cardiac muscle becomes greater and greater, and the ventricle contracts exceedingly rapidly and imperfectly and finally passes into delirium. These cardiac irregularities caused by aconite are antagonized to a considerable extent by atropine. The latter does not prevent the acceleration, but it reduces the tendency to arhythmia and tends to approximate the speed of the ventricle to that of the auricle when the auriculo-ventricular rhythm is disordered, and it averts or delays the very rapid and feeble action of the systole which is the precursor of death. In fact, atropine often enables the heart to stand several times the fatal dose of aconitine. Although the usual cause of death in aconite poisoning is failure of the respiration, it is necessary to pay attention to the condition of the heart, and probably as much good is to be expected from atropine as from any drug.

The blood pressure is extremely irregular during the second stage of the action of aconitine. When the heart is very irregular the pressure falls to nearly zero, but it rises again during the periods in which the heart beats more regularly. It is also fairly high when some simple ratio is maintained between the rate of the auricular and ventricular beats and is lowest when the asequence of the two chambers is most marked. These sudden changes in the blood pressure are undoubtedly due largely to changes in the heart beat, but there is evidence that the vaso-motor centre is also affected. If atropine be administered to an animal in quantity sufficient to paralyze the vagus terminations, aconitine causes a rise instead of a fall of blood pressure. The cause of this rise of pressure is usually considered to be a stimulation of the vaso motor centre, but it is also stated that there is a constriction of peripheral vessels due to a direct action of the drug upon their walls. In the second stage of poisoning the vaso-motor centre is depressed; asphyxia now causes but a slight rise of blood pressure, and the same is true of a stimulation of a sensory nerve (although in this case the possibility of the paralysis of the sensory nerve itself must be considered). The peripheral vaso-motor nerves remain intact, as is shown by the fact that stimulation of the medulla or of the splanchnic nerves causes a rise of blood pressure even late in the intoxication.

Most preparations of aconite contain besides aconitine certain of its decomposition products, especially benzaconine and aconine. Benzaconine, which differs from aconitine only in that one acetyl group has been removed, has an action upon the heart having little resemblance to that of aconitine; in fact, it acts to some extent as an antagonist of aconitine. Instead of causing a great acceleration of the heart as do large doses of aconitine, it slows the heart, especially the ventricles, and if incoordination between auricle and ventricle is produced the latter beats more slowly than the former; with aconitine the opposite is usually the case. The slowing of the heart is due largely to a direct depression of this organ. It is not due to a stimulation of the inhibitory nerves, either centrally or peripherally, as it occurs after atropine.

Aconine, which differs from benzaconine in that a benzoyl group has been removed, has an action just the reverse of aconitine. Instead of being a cardiac depressant it is a cardiac stimulant and strengthens the heart beat; the blood pressure rises and no disturbances of the rhythm are produced. In fact, it is an antagonist of aconitine and tends to prevent asequence of the auricle and ventricle by facilitating the transmission of impulses from one chamber to the other. It also opposes the tendency of the ventricle to go into delirium.

The action of benzaconine and aconine is, however, so feeble in comparison with that of aconitine that it is improbable that they do more than simply to weaken the action of the latter. It is due largely to these decomposition products that the preparations of aconite vary so much in strength.

A number of other alkaloids derived from the Aconitum genus have been isolated, but they have at present little interest and their action upon the heart is not well known. Among these are pseudaconitine (the alkaloid of Aconitum ferox); lappaconitine, septentrionaline, and cynoctonine—all derived from Aconitum septentrionale; and lycaconitine and myoctonine from Aconitum lycoctonum. In addition to these certain artificial derivatives of aconitine have been prepared recently and studied by Cash and Dunstan.

Another alkaloid closely resembling aconitine, but one which is little known, is delphinine. It is found in Delphinium staphisagria, or stavesacre, along with a number of other bases which may be products of its decomposition.

Veratrum viride. Several species of the genus Veratrum have been found to contain alkaloids which resemble aconitine in their action upon the heart. The only preparations in use as cardiac depressants are derived from the rhizome and roots of the American or green hellebore, veratrum viride. After the administration of veratrum viride to man the first effect upon the circulatory system is a reduction of the force of the pulse; the rate is not at first influenced. A little later the pulse rate is much reduced; in exceptional cases it may fall to 35 or even 30 beats per minute, any alarming symptoms which may arise passing away when the administration of the drug is discontinued. The pulse may be moderately full, but it is soft and compressible. If any exertion be made at this stage the pulse becomes very rapid and may become almost imperceptible. The slowing is especially marked during sleep, the patients thus exhibiting an intensification of the ordinary physiological law in virtue of which the pulse falls during sleep. The reduction in pulse rate is often accompanied or followed by nausea and vomiting; there seems, however, to be no connection between these, for if the drug is administered with care a very marked reduction of the pulse rate may occur without any nausea being produced. Decided muscular weakness accompanies the depression of the pulse. Profuse perspiration also occurs; this is frequently attributed to the low blood pressure, but as the drug stimulates the cutaneous glands of frogs it is not improbable that it has some direct action upon the terminations of the sweat glands. After toxic doses there are also a fall of temperature and convulsions as in aconite poisoning and a running, almost imperceptible pulse.

Efforts have been made to analyze the action of the veratrum alkaloids by experiments upon animals, but these have not as yet been entirely satisfactory. This result is due largely to the confusion which has prevailed as to the chemistry of these bodies, so that it is not always certain with what substances the various investigators have worked. According to Wright and Luff the following alkaloids occur in veratrum viride: jervine, pseudojervine, cevadine, very little rubijervine and traces of veratrine and veratralbine. The alkaloid called by Wright and Luff "cevadine" has the empirical formula $C_{32}H_{49}NO_9$; this is usually called "veratrine" or the "crystalized veratrine of Merck," and will be so designated here. There are three modifications of this veratrine, one crystalline and two amorphous; they all have the same physiological action. The alkaloid called by Wright and Luff "veratrine" has the formula $C_{37}H_{53}NO_{11}$; its physiological action is not well known. Bullock discovered an alkaloid in veratrum viride which he named veratroidine; this seems to have been a mixture of rubijervine and an almost inert resin. Wood studied the physiological action of jervine and the so-called veratroidine. The alkaloids the physiological action of which have been most studied in Europe have been derived from veratrum sabadilla (Asagrœa officinalis) and V. album. The seeds of the former contain veratrine ($C_{32}H_{49}NO_9$), the veratrine of Wright ($C_{37}H_{53}NO_{11}$), and cevadine. A mixture of these alkaloids constitutes the Veratrina of the United States Pharmacopœia. Of these alkaloids only veratrine has been carefully studied, but it is not certain that the earlier investigators worked with pure preparations. Veratrum album contains protoveratrine, jervine, pseudojervine, rubijervine, protoveratridine, and others; of these the physiological action of protoveratrine is best known.

Thus the alkaloids of veratrum viride the physiological action of which is known are jervine, veratrine, and rubijervine. The effects produced by preparations of the entire drug are doubtless due largely to these three bodies, and a brief résumé of their action will be given.

The principal investigation of the physiological action of jervine has been made by Wood (*Amer. Jour. of the Med. Sciences*, 1870, and Philadelphia *Medical Times*, iv., 1874), and the following account is taken from his papers. After the administration of jervine to an animal the pulse is generally, if not invariably, lessened in frequency, provided the animal is quiet. When there are convulsions or even marked tremors the pulse becomes very rapid. The arterial pressure is greatly lowered, falling progressively from the beginning to the end of the experiment. The force of the individual beats appears not to be much altered at first. According to Wood these effects are not due to a stimulation of the cardio-inhibitory nerves, for they occur after section of these nerves.

Stimulation of the peripheral ends of the vagi in animals under the influence of jervine caused the usual cardiac results. The alkaloid lessens the arterial pressure after division of the spinal cord—*i.e.*, after vaso-motor paralysis; it also paralyzes the heart of the frog or turtle when placed directly upon it. From these experiments Wood concludes that jervine lowers the force and frequency of the cardiac beats by a direct action upon the cardiac muscle or its contained ganglia. Apparently, however, Wood did not exclude the possibility of the slow heart being due to a stimulation of the vagus endings. Stimulation of sensory nerves or asphyxia caused little or no rise of arterial pressure, indicating a paralysis of the vaso-motor centre.

Wood also studied the action of an alkaloid which he called veratroidine; this, as has been already noted, seems to be a mixture of rubijervine and a resin. This substance caused at first a slowing of the heart and a fall of arterial pressure. After a time, the pulse still remaining very slow, the individual beats became unusually powerful and the blood pressure became normal; then suddenly the pulse rate became very rapid, the individual heart beats losing much of their extraordinary vigor, but the arterial pressure rising nearly fifty per cent. beyond its original position. If the alkaloid was thrown directly into a vein there was a very rapid fall, and then a remarkable rise of blood pressure; the latter is due to asphxyia and did not occur if artificial respiration was maintained. The slowing of the heart was due to stimulation of the cardio-inhibitory centres in the medulla; it did not occur if the vagi had been divided. If, moreover, marked slowing had occurred with intact vagi, section of these nerves was followed by a great acceleration. The slowing was especially marked when the spinal cord had been cut so as to paralyze the accelerators; under these circumstances Wood saw gr. $\frac{1}{80}$ of the alkaloid completely stop the heart, which however commenced to beat again when the vagi were divided. After large doses the slow pulse was replaced by a very rapid one; that this was due, at least in part, to paralysis of the vagus termination was shown by the fact that stimulation of the vagus now had no effect upon the heart. Enormous doses thrown directly into the circulation killed the cardiac muscle directly. Veratroidine (rubijervine) had little or no effect upon the vaso-motor system. Asphyxia or stimulation of a sensory nerve caused a great rise of arterial pressure just as in normal animals.

The action of veratrine upon the mammalian heart resembles in general that of aconitine, except that the stimulation of the cardiac muscle is not so marked. Bezold and Hirt ("Untersuchungen aus dem physiolog. Laboratorium in Würzburg," 1867, p. 95) describe the effect upon the circulation in mammals as follows: The first effect of a small dose is a slight acceleration of the heart, probably due to direct stimulation to the cardiac muscle; then comes a slowing of the heart. With a large dose the latter is the first effect; the pulse rate may be reduced to one-half or one-third the previous rate. Section of the vagi now is followed by an acceleration of the heart; this shows that the medullary centres of the cardio-inhibitory nerves are stimulated just as in aconite poisoning. At the same time there is an increase in the irritability of the vagus endings in the heart, for electric stimulation of the peripheral end of this nerve, which in the unpoisoned animal had no effect, produces a marked slowing after the administration of the drug. If the vagi be divided before the administration of the alkaloid, then this causes an acceleration of the heart, showing that the cardiac muscle is affected directly. This acceleration is followed by a slowing of the heart; this seems to be due to a direct poisoning of the heart muscle. With larger doses the heart is slowed still more, and now the strongest stimulation of the vagi has no effect upon the heart, showing that the vagus endings are paralyzed. These facts indicate that large doses reduce the irritability of the cardiac muscle and paralyze the terminations of the vagi, whereas small doses increase the irritability of both.

After a very large amount of veratrine the heart becomes irregular; unlike the heart in aconitine poisoning, however, it remains slow. The irregularity consists chiefly in the ventricle assuming a rhythm slower than that of the auricle; the ventricular beats then become weak and of a peristaltic character. Little blood is expelled, and the ventricle becomes widely distended and finally stops in diastole; even electrical stimulation does not cause a contraction—indicating a profound poisoning of the cardiac muscle.

Small amounts of veratrine stimulate the vaso-motor centre; this and the slight stimulation of the cardiac muscle cause a rise of blood pressure. After larger amounts the vaso-motor centre is depressed; this increases the fall of blood pressure caused by the slow heart. Bezold and Hirt ascribed the fall of pressure in part to a stimulation of the depressor nerve, but later investigators have failed to confirm this view. Lissauer (*Archiv für experiment. Path. und Pharmakol.*, xxiii., p. 36, 1887) has obtained results slightly different from those of Bezold and Hirt. Thus, he thinks the chief action of veratrine is upon the vaso-motor system and that the heart is not as much depressed as was thought to be the case by Bezold and Hirt. Lissauer found no paralysis of the vagus endings.

Hedbom (*Skand. Archiv für Physiologie*, viii., p. 197, 1898) has recently contributed a very interesting article on the action of veratrine upon the isolated mammalian heart. The heart (of the rabbit) was kept alive by the circulation of a mixture of blood and normal saline solution through the coronary arteries—*i.e.*, by a modification of Newell Martin's method. The contractions were recorded by a thread attached to the ventricle and moving a small lever. When a very small amount of veratrine was mixed with the circulating blood there was first a sudden and very considerable (up to forty per cent.) increase in the amplitude of the contractions. This increase in the amplitude was due to a more complete systole, *i.e.*, to a greater shortening of the muscle fibres. Soon the relaxation became less complete and so the amplitude decreased again. There was usually a slight acceleration of the heart (as described by Bezold and Hirt); this was followed by a marked slowing. During these slow, large heart beats the individual contractions were much prolonged—up to three and a half seconds. As is well known, one of the most characteristic of the physiological actions of veratrine is the peculiar effect it exerts on ordinary striated muscle; the contraction is increased and enormously prolonged. Bezold and Hirt, Böhm, and others have shown that the ventricle of the frog's heart is affected in a way similar to that of the skeletal muscle. The experiments of Hedbom show that veratrine has a similar action upon the mammalian heart. The slight acceleration of the heart seen immediately after the injection of the drug seems to be due to a direct stimulation of the cardiac muscle; the more marked slowing which follows is probably due to a stimulation of the vagus terminations in the heart, as it is often removed by the administration of atropine. A secondary acceleration follows this slowing of the heart. This appears to be due in part to a paralysis of the vagus terminations, in part to a stimulation of the cardiac muscle. This secondary acceleration is often accompanied or preceded by marked irregularities, resembling those seen in digitalis poisoning. This irregularity is marked by the formation of groups and by the appearance of "missed" beats—*i.e.* strong contractions are followed by very weak, almost imperceptible ones. Finally, the heart muscle is paralyzed.

Thus the action of three of the alkaloids of veratrum viride upon the heart is tolerably well known; that of the others is very imperfectly known, but they seem to resemble those already described. No complete experiments seem to have been made with any of the ordinary preparations of veratrum viride in which all of the alkaloids are present, and it is not altogether easy to form a clear idea of the details of the action of such preparation from what is known concerning these three alkaloids. While chemical analyses show the proportion in which the various alkaloids occur in veratrum viride, we have few data as to the comparative toxicity of the individual alkaloids. It seems, however, that veratrine is more powerful than most of the others, and since, according to Wright and Luff, it is the most abundant alkaloid in veratrum viride, it probably plays a much more important part in the action of the preparations of the crude drug than has been generally recognized. Rubijervine is also very poisonous, but it occurs in small quantities.

From the various experiments described above, assuming that all are trustworthy, we may perhaps draw the following conclusions as to the action of veratrum viride upon the circulation: The slowing and weakening of the heart are due to the stimulation of the medullary centres of the cardio-inhibitory nerves by the veratrine and rubijervine (veratroidine). This slowing may be increased by the stimulation of the vagus terminations by the action of the veratrine. The slowing may be due in part to the direct action upon the cardiac muscle by the jervine, but this effect is doubtless antagonized to some extent by the stimulating action of the veratrine described by Hedbom. In therapeutics this slowing of the heart is the only effect desired, and it will be seen that it is produced to a large extent in the same way as when aconite is used—*i.e.*, by a stimulation of the vagus centre in the medulla. With veratrum viride there is another action, however, which is scarcely shown at all by aconite, viz., a stimulation of the vagus terminations in the heart, and it is possible that veratrum viride may thus cause slowing in some cases in which aconite would fail. The rapid pulse after large doses of the drug is due to a paralysis of the vagus terminations by veratrine and rubijervine and perhaps to some stimulation of the cardiac muscle. At the same time jervine and larger amounts of veratrine weaken the heart by a direct action upon the cardiac muscle. Veratrum viride in large amounts does not tend to produce as rapid a pulse as does aconite, probably partly because all the alkaloids have a less stimulating action on the cardiac muscle and partly on account of the peculiar action of veratrine upon all kinds of striped muscle. The fall of blood pressure caused by veratrum viride is due largely to the slowing of the heart; at the same time the vaso-motor centre is depressed by the jervine and when larger amounts are given, by the veratrine.

The physiological action of protoveratrine, the chief alkaloid of veratrum album, has been studied by Eden (*Archiv für exper. Path. und Pharmakol.*, xxix., p. 440, 1892). As far as its action upon the circulation is concerned this alkaloid does not differ very much from veratrine.

Tartar Emetic.—Tartar emetic is classed with the cardiac depressants for clinical and not for pharmacological reasons. Although it depresses the circulation to a marked degree, it has no such special action upon the heart as have aconite and veratrum viride; in fact its action does not differ greatly from that of several other drugs which, since they have never been used clinically for this purpose, are never thought of as cardiac depressants.

The action of tartar emetic upon the pulse in small doses is closely connected with, and to a considerable extent dependent upon, its action as an emetic, for ordinarily it is absorbed very slowly and in very small amounts. The effect upon the circulation of man is described by Ackermann (*Virchow's Archiv*, xxv., p. 531, 1862) as follows: After a small dose the pulse becomes accelerated as feelings of nausea arise and reaches its maximum rate just before the act of vomiting. Thus in one case the normal pulse rate was 71 per minute; during the period of nausea it rose to 110. The strength of the pulse decreases with the increase in rate, and vice versa. It is not necessary for vomiting to occur; the mere sensation of nausea is sufficient to cause an acceleration of the heart. Any drug (such as apomorphine) or any condition (as sea-sickness, swinging, etc.) which causes feelings of nausea is accompanied by a similar acceleration of the pulse. This acceleration is sometimes attributed to a reflex stimulation of the accelerator nerves, but it is more probable that it is due to a reflex diminution of the tonus of the cardio-inhibitory nerves. Accompanying this change in the pulse rate and probably dependent upon it there is a fall of temperature of the extremities and other symptoms of mild collapse. Thus Ackermann found the temperature of the hands to fall .2 to 3.5° C. during the period of nausea; the temperature under the tongue did not vary. After large doses the pulse becomes very feeble, then slow, intermittent, and irregular and the other symptoms of collapse are very marked. The depression of the central nervous system and of the respiration is doubtless due in part to the circulatory disturbances. These more pronounced effects upon the circulation are probably due in part to a direct action of the poison upon the heart. That antimony does exert a depressing action upon the heart is shown by experiments upon the lower animals; the action is most marked in the case of the frog's heart.

Soloweitschyk (*Archiv für exper. Path. und Pharmakol.*, xii., p. 441, 1880) found that for some time after the administration of antimony (in the form of the antimony-sodium tartrate) to a frog the heart continued to beat regularly; the contractions were at times unusually vigorous and the rate was slightly increased. Then the contractions became irregular and peristaltic; arhythmia of auricle and ventricle soon developed, the latter beating but one-half, then one-third, one-fourth, etc., as rapidly as the former. Finally the ventricle stopped in diastole while the auricles continued to beat feebly. The cardiac muscle does not seem to be paralyzed, for a little helleborein will cause it to commence beating again; only the power to contract rhythmically seems to be destroyed by the antimony. That this stoppage of the heart is not due to a stimulation of the vagi is shown by the fact that atropine has no influence upon it.

It is difficult to state exactly the effects of antimony upon the mammalian heart, for in the experiments hitherto recorded the effects upon the heart were not differentiated from those upon the vaso-motor system. It is very probable, however, that after large amounts of antimony the mammalian heart muscle is influenced in a way very similar to that of the frog, but that this action is obscured by the vaso-motor changes. Injected into a vein or an artery of an animal antimony causes an almost immediate acceleration of the pulse. At the same time the blood pressure falls; this fall of blood pressure is gradual but continuous until it reaches zero and the animal dies. When the fall of blood pressure has become very marked (in many cases when it has fallen to about one-half or one-third its previous height) the heart becomes slow and irregular. The diastolic pauses are greatly prolonged, but the changes in the blood pressure following each contraction are very great, indicating that the heart beat is fairly strong and that the vessel walls are much relaxed. This fall of arterial pressure cannot be ascribed to the weakening of the heart, for it precedes this, and there is no constant relation between the condition of the heart and the height of the blood pressure. The cause of the fall of blood pressure seems to be a paralysis of the peripheral vaso-motor system; the blood-vessels, especially those of the splanchnic area, are dilated and the most powerful stimulation of the medulla oblongata is powerless to contract them. It is not known whether the vaso-motor nerves or the muscle of the vessel walls or both are poisoned; the fact, however, that other unstriped muscle (that of the intestines for example) is not paralyzed points to the nerves or their ganglia being the structures acted upon. It is not impossible that the changes in the heart are in reality due to the great fall of arterial pressure, but the fact that antimony has such a poisonous action upon the frog's heart makes it probable that the mammalian heart is similarly affected. The heart finally stops in diastole; just before the final standstill there is frequently a very brief period during which the heart beats with great rapidity, but the contractions are exceedingly weak and the blood pressure remains very low. The cardiac nerves do not seem to be involved in the later stages of the poisoning. Some have stated that the vagus terminations are paralyzed, but this does not seem to be the case. Immediately after death the heart is found to be unirritable to electrical stimulation.

There are a number of other drugs which affect the circulation in ways similar to the above and which might be classified with the cardiac depressants; that they are not so classified is due to the fact that they have never been used to any great extent for their action upon the heart. Among these substances may be mentioned salicylic and carbolic acids, potassium salts, double salts of copper, zinc and some other heavy metals, chloral, saponin, apomorphine, emetine, muscarin, cholin, pilocarpine, hydrocyanic acid, and the various mineral and organic acids. With some of these drugs it is largely a matter of dosage; small amounts may stimulate the heart while larger amounts depress it.

There are also drugs which may at times relieve, in one way or another, the heart and so act as cardiac sedatives. Thus atropine seems to reduce the sensibility of the nervous structures of the heart to increased pressure, and Brunton has found it useful in some cases of palpitation with high blood pressure and in persons suffering from the effects of cardiac strain following violent muscular exertion. Digitalis was at one time called a cardiac sedative from its power to cause a rapid, irregular, irritable heart to beat slowly and regularly; in such cases the action is exerted largely through the inhibitory nerves and so has a certain resemblance to the action of aconite and veratrum viride, although there are other reasons for placing these drugs in entirely different classes.

Some drugs may have the effect of cardiac sedatives by reducing irritation which has caused, reflexly, palpitation of the heart; thus hydrocyanic acid will sometimes relieve the palpitation caused by indigestion. In some cases local irritation will prevent the most powerful of the cardiac depressants from exerting their normal action. An interesting case of this kind is described by Percy (Trans. Amer. Med. Ass'n, 1863, p. 268). Large repeated doses of veratrum viride had no effect upon the pulse of a patient until two large and very active ascarides were removed from the stomach by vomiting; after this had occurred there was an immediate and marked reduction in the pulse. There are certain mechanical means which produce effects analogous to those caused by the cardiac depressants. Thus pressure over the heart—such as that caused by a plaster—removal of blood by venesection, and the application of cold to the cardiac region all reduce the force and frequency of the heart beat and may be used instead of drugs.

It is difficult to form an opinion as to the extent to which the three chief cardiac depressants—aconite, veratrum viride, and tartar emetic—are employed at present, the practice of physicians varying so much. The general indication for their use has been said to be "increased arterial excitement, sthenic fevers, and severe local inflammations." In the first condition they are used simply to reduce the force and frequency of the pulse; in sthenic fevers they are used not only to lessen the force of the heart but to obtain a relaxation of the peripheral vessels, while in local inflammations it is desired to divert, by their use, the blood into other channels. Pneumonia was formerly thought to be pre-eminently a disease in which these drugs were to be used and all three have been employed very extensively in it. At present they are used to a much more limited extent; this is especially true of tartar emetic, and although many use aconite and veratrum viride, some have discarded all three and use the lancet when they think it desirable to depress the circulation. The reader is referred to the articles in this HANDBOOK on the various disturbances of the circulation for a discussion of the use of these remedies, but a few of the cases in which they are employed will be simply mentioned here.

Aconite seems to give the best results in inflammations of limited extent, especially in tonsillitis, quinsy, and acute sore throat. Much of the relief in these cases seems to be due to the perspiration which follows the depression of the circulation. By diverting the blood away from the inflamed tissues these become less painful and the swelling subsides. Aconite is often serviceable in severe colds, in otitis, and in certain forms of asthma. It is sometimes used in nervous palpitation of the heart and in that occurring in excessive hypertrophy of the heart—although here it may become a very dangerous remedy. Occasionally it will relieve restlessness and give the patient refreshing sleep.

Veratrum viride seems to be used as a cardiac depressant to a more limited degree than aconite; it is probably used more extensively in pneumonia and puerperal fever than in the numerous other conditions for which it has been recommended.

Tartar emetic is probably used still less for its action upon the circulation, although it is praised very highly in typhus and other fevers when there is much excitement and wild delirium. It is used much more extensively as a diaphoretic, although its action as such may depend to some extent upon its power to depress the circulation.

II. CARDIAC STIMULANTS.

There are a great many drugs which can increase, in one way or another, or under certain circumstances, the force of the circulation; to a few of these which are used largely by physicians for this purpose the name "cardiac stimulants" is applied. Aside from their action on the circulation, these drugs have little in common in either their chemical or their physiological properties. Their action upon the circulation is, moreover, brought about in the most diverse ways, and is often determined to a considerable extent by the previous condition of the circulation. Some act chiefly upon the blood-vessels, others upon the heart; some act reflexly, others directly; while some may cause one kind of change reflexly and just the opposite when absorbed; some slow, others accelerate, the heart. The action of some is very rapid while that of others is slowly developed and long continued. The last-named difference has served as a basis for the only classification of these drugs it seems possible to make. Those which act rapidly are called "cardiac stimulants proper" or simply "cardiac stimulants," those with a slower action "cardiac tonics."

Cardiac stimulants, used in the narrower sense, bring about their effects largely reflexly and are used to prevent or counteract sudden failure of the heart's action. They are used especially in fainting fits or syncope due to sudden emotion, physical injury, poisoning by cardiac depressants, or when the heart fails suddenly in fevers, after snake-bites, etc. The action of most of them is primarily upon the blood-vessels, and the heart is usually influenced only secondarily. They may be administered by inhalation (as is the case with ammonia in smelling salts), by the stomach or subcutaneously or intravenously. When applied to a mucous membrane they exert their influence largely through their local irritating action; some have little action after absorption while others (such as alcohol and ether) are essentially cardiac depressants when they once get into the circulation. These drugs are seldom used when there are organic changes in the heart.

The most important members of this group are alcohol and the various liquids containing it in concentrated form, ether and chloroform—these three only when brought into contact with a mucous membrane or injected subcutaneously—the various preparations of ammonia, camphor, and the volatile oils.

One of the most powerful of all cardiac stimulants is heat applied to the cardiac region. In addition to the above there are many drugs which, under certain circumstances, may act as cardiac stimulants but which are not ordinarily included under that heading.

Alcohol.—Dr. J. J. Abel, who has given considerable attention to the subject of alcohol, has prepared the following summary of its action upon the circulation. (For a more complete account see Dr. Abel's paper in the report of the "Committee of Fifty.")

It has long been a matter of discussion how best to define the action of ethyl alcohol and of alcoholic fluids on the circulatory apparatus. The term "circulatory stimulant," as applied to alcoholics of all kinds, is firmly fixed in medical literature, but it has become impossible, in view of modern analyses, to retain this term in its original significance. The appearances of so-called stimulation are manifest especially in those individuals who are unaccustomed to the use of alcohol, and who possess an excitable vascular apparatus. In such the eyes become more brilliant, a sensation of warmth is experienced in the stomach and on the surface of the body, the sweat glands, the salivary and gastric glands are stimulated, the pulse is fuller and faster, gestures and muscular movements in general are more frequent and more pronounced, and the respiration responds by an increase in rate and depth. The environment often supplements the action of the wine or other beverage in its emotional or intellectual effect. In view of these phenomena it is not strange that mankind speaks of alcohol as a cerebral, circulatory, or respiratory stimulant.

When it comes to the action of alcoholics on the circulatory apparatus, numerous difficulties are encountered; secondary or reflex must be separated from primary actions. But nowhere has modern analysis given us a clearer idea of the true action of a substance than in that of alcohol on the various parts of the circulatory apparatus. What is to follow holds, strictly speaking, for pure ethyl alcohol only. Yet it will be found to hold also for wines, spirits, and other forms of alcoholics which mankind has accepted after long and frequent empirical trials. It must be borne in mind that esters, aldehydes, the small quantities of higher alcohols, the salts, etc., in short the sum of the by-products of alcoholic fermentation, are quantitatively insignificant in comparison with the ethyl alcohol contained in all alcoholics. This becomes strikingly evident when they are studied in the light of toxicology. Thus, 1 litre of brandy will kill 64.9 kgm. of living animals (dogs, rabbits, etc.), while the ethyl alcohol alone of this litre of brandy will kill 64.3 kgm. It is not denied that these by-products have a very important action on the sense of taste and that of smell, and on the functions of the digestive tract, nor that they noticeably enlarge the effects about to be described. It is especially the esters of wines and spirits which are to be thought of in this connection as slightly increasing the action of the ethyl alcohol, as their action is similar to that of alcohol, though more intense, quantity for quantity.

When we inquire into the direct action of alcohol on each of the several parts of the vascular apparatus taken by itself, we reach the following conclusions.

I. *Action of Alcohol on the Isolated Heart.*—Alcohol in small and moderate quantities, that is, in such amounts as are to be found in the blood in any condition far short of intoxication, does not have a direct stimulating action upon the isolated heart of either warm- or cold-blooded animals; indeed, moderate quantities show no appreciable action either in the way of stimulation or depression. The experiments of Martin and Stevens, Hemmeter, Ringer and Sainsbury, Dreser, Diaballa, Bock and others, furnish incontrovertible proof of this statement. But such a statement does not refer to the long-continued daily administration of small and moderate quantities of alcohol, but solely to its administration during brief periods, as in physiological experiments.

In very large doses, such, for example, as result in helpless and perhaps fatal intoxication, alcohol is seen to be a direct and powerful depressant of the heart, weakening first the auricular, later the ventricular systole, causing more or less distention of both cavities, marked slowing of its movements and great diminution of its output of blood. As we shall see later, these positive statements do not stand in contradiction of the fact that alcohol is of frequent and beneficial use in conditions of great depression of the heart or central nervous system. In experiments like those from which the above conclusions were deduced, the heart was severed from all vital connection with the rest of the body.

II. *Direct Action on the Walls of the Arteries and Veins, that is, the Blood-Vessels Removed from all Central Nervous Control.*—Small and moderate quantities of alcohol have no direct action on the walls of the blood-vessels. Very large amounts no doubt have a direct dilating action on the vessels, like that shown for the heart itself. The flushing of the face and other parts of the body so frequently observed after moderate quantities of alcohol is brought about by an action on the central nervous mechanism which controls the calibre of the vessels.

III. *Influence on the Arterial Blood Pressure.*—Here we are dealing with a resultant effect of the work of the heart, and of the peripheral resistance offered by the smallest blood-vessels. These interdependent variables are affected through controlling nerves, and it is evident that here is an opportunity for indirect influences of various kinds.

It must be admitted that blood-pressure measurements are of minor importance to the clinician. It is well known that minor fluctuations in the arterial pressure are of frequent occurrence, and Hensen even affirms that daily changes of 40 to 60 mm. Hg are not uncommon in individuals lying in bed. Arterial pressure, as usually measured, gives us only the lateral pressure on the walls of the larger arteries, and without additional data it gives us no information on that important question, the intensity of the blood flow—in other words, the amount of blood which passes in the unit of time through a given capillary area. Whether an organ will receive its required amount of oxygen and other necessary material must all depend on this. Now the state of constriction of the peripheral arterioles is a factor of the greatest importance in determining the value of this resultant as well as of the arterial pressure. As Krehl, Hensen, and others have pointed out, even during periods of little or no variation in the aortic pressure, considerable variations are possible in the unit quantity of blood passing through the aorta. In other words, variation in the peripheral resistance may be offset in such a way by responsive variations in the action of the heart that a change occurs, either in the way of an increase or decrease in the amount of blood passing through the organs of the body, although aortic pressure remains practically unchanged. As a rule, however, an increase in arterial pressure means an increase in the intensity of the peripheral circulation. Being an important item in the study of the hæmodynamics, blood-pressure determinations cannot be neglected; yet it is necessary to point out, as Hensen has well said, that what we most need to know is not the arterial blood pressure, but rather the relation of the quantitative blood flow in any given organ to the actual needs of that organ, a relation which at present it is impossible to determine.

In regard to the action of alcohol on the arterial pressure, we may say that, given in moderate quantities and in such a dilution as to avoid the consequences of *local irritation*, it has no appreciable effect on it. When so large a quantity is given that a change in the pressure becomes apparent, it is always in the direction of a fall and not of a rise. In the early stages of its action it usually causes some degree of flushing of the skin and brain, and later, when very large quantities have been taken, dilatation of the abdominal vessels occurs. A marked fall of blood pressure due to such large quantities is a toxic phenomenon, and is never met with under ordinary circumstances. It is due to a sedative or depressant action of the alcohol on the vaso-motor centres, and also in part to its action in weakening the heart.

IV. *Action of Alcohol on the Pulse Rate.*—When alcohol or beverages containing alcohol are administered to *healthy* persons in small doses, or even in such doses as will produce transient psychical changes, no alteration of the *pulse rate* is usually observed, provided that local irritation in the mouth and stomach is avoided, and the indirect effects of the mental action of the alcohol, such as bodily movements, are not allowed to influence the experiment. It is not improbable that in some excitable individuals the cerebral effects of the alcohol and the circumstances of its administration may combine to induce such mental effects that slight changes in the pulse rate occur.

As a rule, when the quantity of alcohol administered is not too small, the *character* of the pulse wave undergoes a slight change, the pulse becomes fuller and softer in consequence of a dilatation of superficial arteries. The heart is not weakened at this time, and the fuller pulse may give a false impression and lead to the belief that the arterial tension has been raised. The pulse tracings of Marvaud, Parkes, von Jaksch, Jaquet, and others, show that moderate quantities of alcohol influence the form of the pulse wave in like manner with chloral and other hypnotics, though less markedly from a quantitative point of view. The slight dilatation of the superficial arteries is due to the sedative action of the alcohol on the vaso-constrictor centre of the medulla, and is not sufficient to lower the arterial tension as measured in the carotid.

By virtue of its local action on mucous membranes, and also by virtue of its cerebral effects, alcohol is capable of influencing the several parts of the vascular apparatus in a number of ways often directly opposed to those mentioned above. Such indirect effects are common to its pharmacological congeners, and are familiar in the use of alcohol in daily life and in medical practice. Of these none is more often observed than a quickening of the pulse rate. Such indirect effects must not be allowed to obscure its true inherent action, which is always depressant in kind. When once in the blood and tissues, it must be classed with the anæsthetics and narcotics.

It is not to be inferred that the above statements forbid a reasonable and prudent use of alcohol in therapeutics. The records of clinical medicine show that alcohol, by virtue of its numerous indirect as well as direct influences, often serves the purpose of a "circulatory stimulant." In conditions of shock the weak pulse may become fuller and stronger, the feeble heart may beat more vigorously. Again, a quick pulse may become slower as the rapidly beating, fluttering heart is induced to slow down to a regular rhythm. Other examples need not be cited. The day is happily past when the therapeutist plied his patient with a number of bottles of wine a day in the belief that he could stimulate the heart, lower the temperature, supply nutriment, and effect other good ends, without detriment of any kind, by giving these large quantities. Certainly its administration in excessive doses can only do harm.

Though the pharmacologist cannot admit that this agent is capable of stimulating the isolated mammalian heart, it would be rash to assert that it cannot serve as a cardiac stimulant in the human system. Gutnikow, who accepts it as a proved fact that alcohol can only lower the arterial pressure, when once it has reached the circulating blood, has made it the object of his researches to harmonize this with the equally well-known fact that it is often used in medical practice as an analeptic, as an agent that "strengthens and fortifies the heart." According to this author the sum total of the action of alcohol on the circulation is to the effect that, although there is a condition of lowered arterial tension, yet the mutual relations of the pressures in the cavities of the heart and in the arteries and veins are such that *the heart works as if it were strengthened.* It now has an easier task to keep all the minute arteries and veins and the capillaries well filled; under the new conditions its propelling power is not injured but rather improved. It may well be the case in certain clinical conditions, in the light of the remarks made in a previous paragraph on the relations existing between aortic pressure and the volume of the peripheral circulation, that alcohol will give cause for a better peripheral circulation, although the aortic pressure is slightly lowered.

Whatever may be the future theories in regard to its clinical uses, the old position of alcohol as a blood-pressure-raising agent and heart stimulant can no longer be defended, and it remains for the practitioner to use this agent with care and great discretion.

Ammonia.—The preparations of ammonia which are used for their effect upon the circulation are solutions of the gas in water or in alcohol and the carbonate; the latter is a rather complex mixture of the carbonates and carbamates of ammonia, which give off ammonia on exposure and hence has an action similar to but less powerful than that of the solutions of ammonia.

Ammonia has a very powerful local action as well as an action upon the nerve centres when it reaches the circulation and it is important to distinguish between these. When ammonia reaches the circulation it is converted into urea very rapidly; hence unless considerable quantities are injected at once into the circulation no symptoms are produced. While ammonia is absorbed with considerable rapidity from the stomach, it is doubtful whether after the use of medicinal doses it reaches the circulation in sufficient concentration to have any appreciable effect. Hence the effects of ammonia (and of ammonium carbonate) when given by the stomach are due largely, if not entirely, to the reflexes caused by its local action; the effects of the intravenous injection of considerable quantities will be discussed later.

The effects of ammonia can be elicited by applying it to either the respiratory or the digestive tract or subcutaneously, and consist of a powerful reflex stimulation of the vaso-motor and respiratory centres. The result is a rise of arterial pressure and an improvement in the pulse; the latter is probably dependent upon the rise of blood pressure, for the heart, so far as it is affected reflexly at all, seems to be slowed by a stimulation of the vagus centre. The rise of blood pressure will rouse the patient from a fainting spell, from a condition of sudden collapse, from failure of the circulation during anæsthesia and from similar conditions. The effect is very transitory, but is often sufficient to carry a person through a dangerous period. Both the physiological action and practical experience point to the conclusion that ammonia is of little service when the failure of the circulation is dependent upon some slow and persistent cause. If ammonia is applied to the nostrils for too long a period or in too concentrated a form it may produce inflammation of the respiratory passages; also when it is swallowed in large quantities some of the vapor may reach the respiratory passages and cause death by œdema of the larynx.

When ammonia or one of its neutral salts is injected directly into the circulation of a mammal the effects are those observed whenever a powerful stimulant to the medulla or spinal cord is injected—increase of respiration, convulsions, tetanus, and a rise of blood pressure. These effects are probably due to the irritating action of the ammonia upon the nerve cells rather than to any specific stimulation of them, as is the case with such an alkaloid as strychnine for example. Very similar effects follow the subcutaneous application of ammonia or of its salts, although here the effect is complicated by changes brought about reflexly. The results are the same whatever the salt used, provided the acid in combination has not, of itself, a poisonous action; this shows that the results are due to the ammonium ion.

A considerable amount of a salt of ammonia may be injected into the circulation of an animal without producing any toxic symptoms, provided the injection be made very slowly. Thus Marfori (*Archiv für exp. Path. und Pharmakol.*, xxxiii., p. 71, 1893) showed that .03 gm. of ammonia (in the form of the carbonate) per kilogram could be injected per hour into a dog without causing any symptoms. The explanation of this is that the ammonia is rapidly converted into urea.

The effects of ammonia and its salts when injected rapidly into the circulation or subcutaneously into an animal have been investigated by Blake (*Edin. Med. and Surg. Jour.*, lvi., p. 1, 1841), Lange (*Archiv für exp. Path. und Pharmakol.*, ii., p. 375, 1874), Funke and Deahna (*Archiv für die ges. Physiol.*, ix., p. 416, 1874), and Formanek (*Archives internat. de Pharmacodynamie et de Therapie*, vii., p. 229, 1900). The first effect is usually a slowing of the heart and a slight fall of blood pressure; then there is a marked rise of blood pressure, the heart sometimes remaining slowed, sometimes being accelerated. The slowing of the heart and the first fall of blood pressure are due almost entirely to a stimulation of the centre of the cardio-inhibitory nerves, for they usually disappear immediately upon section of the vagi. There may sometimes be a slight, unimportant slowing of the heart after section of the vagi; this is probably due to a slight stimulation of the vagus endings in the heart, for these are stimulated by a great many of the drugs which stimulate the medullary centres of the vagus. If a very large amount of ammonia is injected into a vein the heart may be poisoned directly and may either beat very slowly or be arrested at once in diastole.

The rise of blood pressure has been attributed by some to a stimulation of the heart, by others to a stimulation of the vaso-motor system; it is due to both of these, but probably more to the latter than to the former. The action of the salts of ammonia when directly applied to the frog's heart has been studied by Ringer and Sainsbury. These results are of especial value because no similar experiments have been made upon the mammalian heart. Briefly stated, Ringer finds that ammonium salts added to the nutrient fluid circulating through the isolated frog's heart increase, in small doses, the strength of the ventricular contractions, but that larger doses destroy muscular contractility; spontaneous action, however, continued until contractility was lost; in the end stage there was no response even when the ventricle was strongly stimulated electrically. Ringer also finds that ammonia lessens dilatation of the ventricle and arrests it in systole. If the heart has been weakened by chloroform or other anæsthetics, the beat is strengthened by ammonia, and a heart stopped in diastole by chloroform passes into the condition of systole under the influence of ammonia. Since these experiments were made upon the ventricle of the frog's heart we are justified in concluding that ammonia stimulates the cardiac muscle directly. It is not known to what extent ammonia has a similar action upon the mammalian heart. An acceleration and strengthening of the heart beat sometimes follows its injection, but this stimulation is usually of short duration and does not always occur. Some think that the improvement in the heart beat is to be attributed to the rise of blood pressure rather than to a direct effect upon the heart, while Formanek thinks it is due in part to a stimulation of the accelerator nerves.

The great rise of blood pressure following the injection of ammonia is usually attributed to a stimulation of the vaso-motor centre, and this view is made very probable by the fact that the other medullary centres are so powerfully stimulated by this substance. Funke and Deahna found that in frogs section of the cord or of the sciatic plexus greatly diminished or abolished altogether the constriction of the blood-vessels following the subcutaneous injection of ammonia. On the other hand, there is considerable experimental evidence that the peripheral vaso-motor system (the nerves or the muscles of the vessels) is stimulated directly. Thus Lange obtained a marked rise of pressure after division of the cord, *i.e.*, after the vaso-motor centre had been separated from the arterioles. Beyer (*Medical News*, 1886) transfused the vessels of terrapins (from which the heart had been removed) with Ringer's solution to which salts of ammonia had been added. There was first an increased then a diminished outflow from the veins, *i.e.*, a dilatation followed by a constriction of the blood-vessels. We are probably justified in concluding that the rise of blood pressure caused by ammonia is due partly to a stimulation of the vaso-motor centre and partly to a direct action upon the arteries; it is very probable that direct stimulation of the heart also is a factor, especially if this organ has been previously weakened by anæsthetics, etc. Binz (*Centralbl. für klin. Med.*, ix., p. 26, 1888) found that if the arterial pressure of an animal was made very low by the administration of chloral hydrate, ammonia would cause it to rise; the improvement was, however, temporary and when the ammonia was pushed convulsions followed.

Intravenous and hypodermic injections of ammonia are sometimes made in cases of sudden and dangerous collapse, as in failure of the heart during anæsthesia, in cholera, after injuries, etc. It has been used extensively in cases of poisoning from snake bite but the improvement in these cases seems to be temporary. When ammonia is administered by the mouth or by the respiratory tract the only effect upon the circulation is the reflex stimulation of the vaso-motor centre; by its intravenous use the peripheral vaso-motor system as well as the medullary centre is stimulated and there is further probably some direct action upon the heart. When ammonia is given intravenously in very large amounts there is danger of causing convulsions; animals, however, usually recover quickly from such convulsions.

Camphor.—Camphor has long been used, especially in Germany, as a cardiac stimulant in cases of collapse and cardiac weakness from fevers and other causes; the pulse becomes fuller and stronger under its influence. Statements as to the action of camphor upon the heart are incomplete and in some cases contradictory; moreover, its cardiac action is undoubtedly much obscured by its action on the central nervous system, the respiration, and the vaso-motor centre. The beneficial effects in collapse, etc., are probably due quite as much to these effects as to the effects upon the heart. Camphor has, moreover, a well-marked local action and it is not easy to distinguish between the effects produced reflexly and those produced after its absorption.

Some of the rather fragmentary statements as to the action of camphor will be given. Lewin (*Archiv für exper. Path. und Pharmakol.*, xxvii., p. 229, 1890) found that camphor administered to rabbits in which the blood pressure was extremely low as a result of large doses of chloral hydrate caused a marked rise of pressure; frequently it was doubled. The rise of blood pressure was longer continued when the camphor was given by the stomach than when it was injected into a vein. Lewin argues that since the vaso-motor centre was paralyzed by the chloral the rise of blood pressure must have been due largely to a stimulation of the heart (for camphor has, so far as is known, no direct stimulating action upon the peripheral vessels). If the chloral anæsthesia was not so very deep then the vaso-motor centre was stimulated, as was shown by the fact that it became sensitive to the effects of asphyxia.

It is a significant fact, however, that Wiedemann (*Archiv für exper. Path. und Pharmakol.*, vi., p. 228, 1876) failed to obtain any rise of blood pressure from the administration of camphor after section of the spinal cord—as would be expected if Lewin's conclusions are correct. It is very probable that there was some source of error in the experiments of one or the other investigator. Their results could, however, be brought into accord if we suppose the medullary centres of the accelerator nerves to be stimulated by the camphor. There is, however, no experimental basis for the latter supposition.

Small doses (five to ten grains) administered to a healthy man usually cause an acceleration of the pulse, although sometimes they have little effect or may even cause slowing. Larger doses (twenty grains or more) slow and weaken the pulse; after toxic doses the pulse may be accelerated again.

When from any of a number of causes the pulse is very weak or almost imperceptible, camphor will make it fuller and stronger. Binz and Baum found that in animals in which fever had been induced by the injection of putrid matter, camphor increased the strength of the heart beat and caused it to continue longer after death than in the case of control animals.

Heubner (*Archiv für Heilkunde*, xi., p. 334, 1870) and Harnack and Witkowski (*Archiv für exper. Path. und Pharmakol.*, v., p. 427, 1876) state that camphor causes the frog's heart to beat more slowly but more powerfully; this is due, according to these authors, to a direct action upon the heart, for the latter can be made to beat again after it has been brought to a standstill by muscarine, and, on the other hand, neither muscarine nor stimulation of the vagus can stop the heart poisoned with camphor. Lewin (*loc. cit.*) found the frog's heart to be slowed by a prolongation of the systole; the diastole was less complete and so the output was diminished. Thus the effect of camphor upon the frog's heart is similar in some respects to that of digitaline.

The blood-pressure in mammals is usually considerably increased by camphor; this seems to be due in part to an action upon the heart, in part to a stimulation of the vaso-motor centre. Whether the latter is stimulated directly or reflexly is not known. In some cases rhythmical variations of the blood pressure appear; these are especially marked if convulsions occur, but they are also seen when convulsions are prevented by curare (Wiedemann, *loc. cit.*). It has been suggested that these rhythmical variations are due to a direct action upon the vaso-motor centre, just as the convulsions are due to a direct action upon the cerebral cortex; or the cerebral cortex may send rhythmical impulses to the vaso-motor centre independently of those causing the convulsions.

Thus, as far as we are able to judge from the available data, camphor has an action upon the circulation similar to that of ammonia, and it seems to be of use in similar conditions. Like that of ammonia the action of camphor is very transitory. Van der Helm ("Versuche über einige arzneiliche Erregungsmittel," Dissert., Bonn, 1887, p. 28) says that the action of camphor upon the blood pressure, as well as upon the respiration, is longer continued than is that of ammonia. Attention was called above to the fact that the effect of camphor is more lasting when it is given by the stomach than when injected intravenously; the explanation of this is probably that in the latter case the camphor is very rapidly destroyed in the organism. Moreover, when the drug is given by the stomach, the reflex as well as the direct effects of its action are obtained. The slight solubility of camphor in water and the consequent great irregularity of its rate of absorption from the digestive tract are two of the chief drawbacks to its employment in therapeutics. A number of the other members of the camphor group have been studied, but as yet no good substitute for camphor has been discovered. Camphorol, amido-camphor, and camphoric acid resemble camphor in their physiological action but are less powerful.

Musk has also been used as a cardiac stimulant in conditions similar to those for which camphor has been prescribed; it has been especially recommended in certain cases of advanced typhoid fever. Almost nothing is known as to its physiological action, but it seems to strengthen the heart beat; it has a more decided action upon the respiration.

Most of the volatile oils when taken into the stomach act as mild cardiac stimulants. Their action is entirely a reflex one, for when injected into a vein they depress the vaso-motor centre and, in large doses, the heart.

Cardiac Tonics.—Those drugs which are employed to produce a more lasting effect upon the heart are called cardiac tonics. They act chiefly upon the cardiac muscle; to a less extent upon the cardiac nerves and the vaso-motor apparatus. Their action is usually slow; frequently no change in the circulation can be made out for many hours, sometimes not for days, after their administration has been begun. It is chiefly in diseases of the heart, especially those associated with valvular lesions in which dilatation has occurred, that these drugs are used. Among them are some of the most valuable remedies known to medicine.

The most important members of this group are those belonging to the "digitalis series," including digitalis itself, strophanthus, scilla, convallaria, adonis, erythrophlœum, helleborus niger, etc. Caffeine and strychnine, as far as their action upon the heart is concerned, also belong to the group of cardiac tonics.

The Digitalis Series.—The "digitalis series" embraces a number of substances derived from various families of the vegetable kingdom and having little in common as regards their chemical composition; some substances found in the animal and even in the mineral kingdoms may be included in this series. The bond that unites these various substances is a peculiar and specific influence upon the heart; the action of any one member is almost identical with that of all the others and different from almost all other substances. So great is this similarity of action that pharmacologists do not hesitate to apply the discoveries made concerning one member to all the others and speak of the action of "digitalis," although the experiments in questions were made with some other member.

The three drugs of this series which are most used are digitalis, strophanthus, and scilla, and most of the physiological experiments have been made with these, especially with the first two.

Few drugs in the Pharmacopœia have been the subject of so much discussion as digitalis, and even yet writers are not in accord as to some of its physiological actions. Clinicians formerly classed it with the cardiac sedatives, although now it is placed first in the list of cardiac stimulants or tonics. Different experimenters have credited it with having nearly every action upon the vascular mechanism which it is possible for a drug to have. These discordant results are all the more remarkable as they are not due to the workers having used different preparations; almost any preparation of these drugs, provided it is active at all, will produce the effects typical of the series. The real source of trouble has been that the pharmacologists and physicians have failed, until very recently, to make use of the advances in methods of work and of the facts discovered by modern physiology.

Very little knowledge of the action of digitalis upon the circulation can be obtained by its administration to healthy men beyond the fact that the pulse first becomes very slow and later intermittent and irregular. The apex beat is stronger and the arteries feel more tense. At the same time the irritability of the heart seems to become abnormally great; slight exertion may cause it to assume a rate of 120 to 130.

Experiments upon the frog's heart have played a very important part in the history of the study of the physiological action of digitalis; the greatest service such experiments have rendered is the proof that the action of digitalis is primarily upon the cardiac muscle. The changes brought about in the frog's heart are readily observed by exposing the heart and injecting the drug into a lymph space. The heart soon becomes slowed, but the essential feature is that the ventricular systole becomes more complete. The blood is more completely expelled from the heart, and during each systole the ventricle becomes almost white; it also remains contracted for a longer period. The diastole becomes shorter and then less complete; the time relations between systole and diastole become almost reversed. Instead of a short, sudden systole and a long-continued diastole, as normally, the systole becomes very long while the diastole is a sudden, imperfect relaxation of very short duration which merely interrupts for an instant the prolonged contraction. Finally the ventricle stops in systole; it is firmly contracted and white, while the auricles are distended with blood and may contract feebly for a short time. Before the ventricle is finally arrested certain irregularities usually appear. One part of the ventricle, usually the apex, does not relax during diastole and the blood is thrown against the relaxed walls of the other parts causing little bulgings. Or the ventricle may assume a mottled appearance from there being numerous small areas of muscle which remain contracted. The blood may be thrown from one side of the ventricle to the other, the heart undergoing the "peristaltic contractions" so often mentioned by German writers.

The picture of the frog's heart under digitalis is an extremely characteristic one, and such an experiment as the above is of much more value as a means of identifying one of this series in toxicological examinations than are most of the chemical tests.

If, after the ventricle has stopped, the intracardiac pressure be increased, the heart will commence beating again, showing that the cardiac muscle is not in a condition of rigor. If apomorphine, or some other drug which tends to paralyze the heart muscle, be applied to the contracted ventricle, the latter will relax and commence beating again. These facts led Schmiedeberg to the view, which has been widely accepted, that the essential action of digitalis upon the cardiac muscle is a change in its elasticity. There are certain facts which make it difficult to accept this view of Schmiedeberg's, and the only statement we can safely make is that digitalis tends to increase and prolong the contraction of the heart and to diminish and shorten diastole. The absolute power of the heart muscle—*i.e.*, the pressure against which the heart is able to contract—does not seem to be increased by digitalis. Since the extent of the contraction is increased, the effect of digitalis has been compared to an increase in the length of the muscle fibres while their cross section (which determines the absolute power) remains the same. That this action of digitalis is upon the cardiac muscle itself, and not upon nervous structures contained in the heart, is shown by the fact that entirely similar changes are produced in the apex of the frog's ventricle and in the hearts of certain invertebrates which are free of nerve cells. So specific is the action of digitalis upon the heart that this organ may be completely stopped in systole and yet the frog jump about very much as if it were normal, *i.e.*, the central nervous system and skeletal muscles are very little affected when the action upon the heart is at its maximum.

These effects of digitalis upon the cardiac muscle are sometimes obscured by the results of a stimulation of the vagus caused by the drug. In some cases after the application of digitalis the systole is incomplete while the diastole is much prolonged and the relaxation during it very great; the heart may even stop temporarily in diastole. Section of the vagi or the paralysis of their endings by atropine causes this picture to change instantly and the results are now as those described above.

One other action of digitalis upon the frog's heart is to be noticed, viz., an increase in its irritability. That the irritability of the muscle is increased is shown by the fact that a preparation of the apex of the ventricle which has been exhausted by the transfusion of normal saline solution through it and which has ceased to beat will commence again when digitalis is applied to it. Sometimes there is a slight acceleration of the heart immediately after the injection of digitalis; this is doubtless due to an increase in the irritability of the muscle.

The study of the effects of digitalis upon the frog's heart is of importance because the changes produced by it in the mammalian heart can be traced back to the same two factors—an alteration of the cardiac muscle combined with a stimulation of the cardio-inhibitory nerves.

The action of digitalis upon the circulation of mammals is usually divided into four stages (Schmiedeberg, *Archiv für exper. Path. und Pharmakol.*, xvi., p. 175, 1882).

1. Rise of arterial pressure accompanied as a rule by slowing of the heart.
2. Continued rise of blood pressure with increase in the pulse rate.
3. Continued high pressure with great irregularity of the heart.
4. Rapid sinking of the blood pressure, failure of the heart, standstill, and death.

Such a division of the action into stages serves a useful purpose in so far as it emphasizes some of the salient points; but as a matter of fact these stages merge into each other and frequently some of the features of one appear in the others. Some of the chief points to be considered, then, are (1) the slowing of the heart, (2) the rise of blood pressure, (3) the secondary acceleration of the heart, and (4) the cause of the irregularity and death of the heart.

The slowing of the heart was observed in man by Withering, by whom digitalis was introduced into medicine ("An Account of the Foxglove and Some of its Medical Uses; with Practical Remarks on Dropsy and Other Diseases," Birmingham, 1785). Withering was chiefly interested in the diuresis produced by digitalis and paid but little attention to its action upon the heart, although he remarked "that it has a power over the motion of the heart to a degree yet unobserved in any other medicine and that this power may be converted to salutary ends." John Ferriar wrote an essay in 1799 on the action of digitalis in which he states that the chief action is to slow the heart. The first efforts to discover the cause of this slowing of the heart seem to have been made by Traube in 1851. Traube found that the slowing was removed by section of the vagi, and he therefore ascribed it to a stimulation of the cardio-inhibitory centre in the medulla—an explanation which has received abundant confirmation. Occasionally digitalis causes a slight slowing of the heart after section of the vagi; this has been shown to be due to a stimulation of the vagus endings in the heart. The irritability of the vagi is increased by digitalis, for a stimulation of these nerves which was inefficient before, will slow the heart after its administration. An attempt was made to show that the stimulation of the vagus centre was not a direct effect of the digitalis but a secondary effect due to the rise of blood pressure; this is disproved by the fact that the heart is often slowed although there is no rise of blood pressure.

Thomas observed that digitalis sometimes failed to slow the heart in pneumonia; Brunton and Cash investigated the cause of this and reached the conclusion that it was due to a partial paralysis of the medullary centres of the vagi by the fever so that they were no longer easily stimulated by the drug. Hence if digitalis is given in a case of fever, the rate of the pulse is not always a safe guide as to whether the drug has been given in sufficient quantity to affect the cardiac muscle.

The acceleration of the heart which occurs in the later stages of digitalis poisoning was at first attributed to a paralysis of the vagi, for a number of investigators failed to obtain any slowing of the heart by stimulating these nerves during this stage. This explanation has proved insufficient because in some experiments the vagi retain their control over the heart up to the end, and, moreover, digitalis causes an acceleration of the heart after the vagi have been paralyzed by atropine. Attention was called above to the fact that the irritability of cardiac muscle of the frog is increased by digitalis, and, as will be shown later, there is abundant evidence that the same occurs with the mammalian heart. Hence at present it is considered that the acceleration may be due in part to the paralysis of the vagi, but that the increased irritability of the cardiac muscle which renders the heart more difficult of inhibition is a more important factor. Of course, the acceleration may be due in part to a stimulation of the accelerator nerves, but there is no clear proof that this is the case.

The rise of blood pressure caused by digitalis has been a matter of much dispute. Blake (*Edinburgh Med. and Surg. Jour.*, April, 1839) was the first to make blood-pressure experiments with digitalis; he concluded that the rise was due to a contraction of the capillaries and other peripheral vessels. A group of German investigators (among them Schmiedeberg and his pupils) have always maintained that the increased strength of the heart beat is the cause of the rise of blood pressure. They based their view upon experiments upon the frog's heart as well as upon deductions drawn from the behavior of the mammalian heart. There has been much discussion as to whether the vaso-constrictor centre is involved in the rise of pressure; there is no question that a marked rise occurs after section of the spinal cord, but it is not yet settled whether, in the intact animal, stimulation of the vasomotor centre may not be a factor in the cause of the rise of blood pressure. A large amount of evidence has accumulated which shows that the peripheral vessels are constricted by digitalis. Thus Donaldson and Stevens (*Journal of Physiology*, iv., p. 165, 1883) observed a marked diminution in the outflow from the veins of a terrapin (in which the central nervous system had been destroyed and the heart removed) when digitalis was added to the solutions transfused through the vessels. Similar results have been obtained in transfusion experiments with the kidneys and other "surviving" organs of mammals. On the whole the evidence is very strong that, in a normal animal, the constriction of the arterioles, due to a direct action upon their muscular walls, is a very, perhaps the most, important factor in the rise of blood pressure. Stimulation of the cardiac muscle is another factor, and it is probable that there is also some stimulation of the vaso-constrictor centre. In the case of a man with incompetent valves, the heart action is probably a much more important factor in causing the rise of blood pressure than it is in a normal individual. This point will be discussed later.

The fall of blood pressure and the irregularities of the heart in the late stages of digitalis poisoning are attributed entirely to changes in the heart. It has been shown that there is no dilatation of the arterioles, as was once supposed to be the case, even after very large amounts of the poison.

Until comparatively recently very little was known as to the details of the changes produced by digitalis in the mammalian heart; that the strength of the beat is increased was generally inferred from the experiments upon the frog's heart. Moreover, several English physicians in the earlier part of the century (*e.g.*, Beddoes and Kinglake, 1801) had reached the conclusion, from studying the pulse, that while digitalis slows the heart, the strength of the beat is not decreased, but is, on the contrary, increased. The increased energy of the heart's contraction is also evident from a study of the pulse waves in an animal deeply poisoned with chloral. Chloral causes a complete relaxation of the arterioles. If digitalis be administered to an animal in which this has occurred the pulse waves are greatly increased, indicating that the heart is expelling more blood at each contraction. It has been a debatable question whether this increased output of the heart is due to a change in systole or in diastole. Schmiedeberg ("Grundriss der Arzneimittellehre," dritte Auflage, p. 168, 1895) and Williams (*Archiv für exper. Path. und Pharmakol.*, xiii., p. 9, 1880) maintain that there is an increased diastolic extensibility without any change in the contractility. According to these authors, the elastic resistance of the heart is diminished and there is an increased diastole. As the heart contracts to its former volume in systole more blood is expelled and consequently more work accomplished.

More recent workers have adopted the view that the essential change is one in systole, but that this is combined with the effects of a stimulation of the vagi (Cushny) or of the vagi and accelerators (François-Franck). François-Franck (*Clinique Médicale de la Charité*, Potain, p. 549, 1894) pointed out the resemblance between the action of digitalis upon the heart and the effects of the simultaneous stimulation of the vagi and accelerators; in each case there is a slowing of the pulse but an increase in its force. At the same time the increase in force is due, according to this author, in part to a direct muscular action. In a later paper (*Comptes rendus de la Société de Biologie*, 1897, p. 111) he seems to lean toward the view that the change in the muscle is a more important factor than he at first supposed. Cushny (*Journal of Experimental Medicine*, ii., p. 254, 1897) advanced, independently, a theory for the action of digitalis very similar to that of François-Franck, except that he ascribes those changes which the French writer thought to be due to a stimulation of the accelerators entirely to the muscular action.

As the methods used by Cushny are probably more exact than those of others his results will be given in some detail. Cushny studied the effect of digitalis upon the heart by means of the myocardiograph and the cardiometer of Roy and Adami. The former is an instrument with which the distance between two points on the heart's surface and their movements relative to each other are recorded. The curve made by this instrument is similar to an ordinary muscle curve and shows not only the rate of the heart beat but also its strength and changes in tonicity; *i.e.*, whether the heart tends to assume the position of systole or that of diastole. The cardiometer measures the volume of the heart in its successive phases and therefore records the amount of blood expelled from the heart. The experiments of Cushny were made upon dogs and cats. The action of digitalis may be divided into two stages: the first stage is characterized by a slow pulse due to stimulation of the vagus, while in the second stage the heart is accelerated. In both stages there are very important changes in the cardiac muscle. The first stage may be divided into the "therapeutic stage" and a stage of "excessive inhibition"; the latter stage does not always occur. The early part of the first stage is the one of greatest interest as it is the only one desired in the medicinal use of digitalis.

Within one or two minutes after the intravenous injection of a very small amount of digitalis changes in the heart occur which are characterized by a slowing of the beat and increased excursions of the recording levers toward systole and generally toward diastole. The slowing of the heart, being caused by stimulation of the vagi, is due largely to a prolongation of the diastolic pauses. At the same time the duration of the systole is somewhat increased; but this seems to be due entirely to the slowing of the heart, for there is no evidence that the contraction of the mammalian cardiac muscle is prolonged, as is so markedly the case with the frog's heart. The increased excursion toward systole of the lever fixed to the ventricle shows that this cavity is emptying itself much more completely than it normally does. It is generally recognized that normally the ventricles do not empty themselves completely so that at the end of systole they contain some blood. Under the influence of digitalis the blood remaining in the ventricle at the end of systole is much less than before. This increased contraction of the ventricle is due to an action of the drug on the cardiac muscle, just as in the frog's heart. The papillary muscles undergo the same change as the rest of the ventricular wall, contracting more strongly and more completely than before the administration of the drug. The intraventricular pressure during systole was found by François-Franck to be much increased. The relaxation of the ventricle during diastole varies considerably in different conditions. As is well known, stimulation of the vagus always tends to increase the relaxation of the ventricle, but in the case of digitalis this action is opposed by the direct effect of the drug upon the heart muscle. The result depends upon these opposing factors, and the effect of these again depends, largely, upon the condition of the heart. If the heart is normal or does not dilate much during diastole, digitalis increases the relaxation (Fig. 1141, *D*). If, however, the heart is weak and dilated digitalis tends to lessen this dilatation so that the relaxation of the ventricle during diastole is less than before the administration of the drug; this is always the case if the vagus terminations have been paralyzed by atropine (see Fig. 1142, *B*).

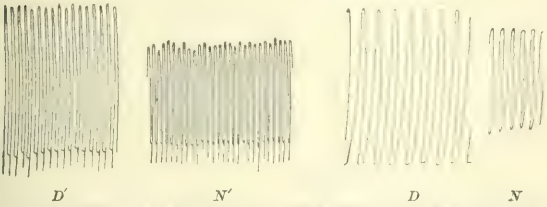

FIG. 1141. Tracings of the Ventricular Contractions under Digitalis in Experiments on Two Dogs. *N*, *N′*, Normal contractions; *D*, *D′*, contractions under digitalis. The levers move upward during systole. In *D* the rhythm is slower and the movements extend further upward and downward than in *N*, *i.e.*, the contractions are more complete and the dilatation during diastole is greater. In *D′* the rhythm is slower, and the tracing extends further upward than in *N′*, but reaches almost the same point below, *i.e.*, the contraction is stronger, but the dilatation is scarcely changed. (From Cushny.)

In the auricles the same forces are at work as in the ventricle. The direct muscular action tends to cause a more complete contraction in systole while the stimulation of the vagus opposes this action as well as causes a slowing of the beat. As is well known, stimulation of the vagus produces a much greater effect upon the auricle than upon the ventricle, while there is a much smaller amount of muscular tissue upon which the digitalis can act directly. Hence after even a comparatively small dose of digitalis the inhibitory action may at times predominate and thus greatly reduce the extent of the contraction of the auricles and so the volume of blood expelled. With ordinary medicinal doses, however, the effect upon the auricles is very much the same as that upon the ventricles: the heart beat is slowed, but the contraction in systole is increased while the relaxation in diastole is not much influenced.

It is clear that the output of the ventricle at each beat must be increased by digitalis, for the ventricle usually contains more blood at the beginning and less at the end of systole than normally. If the rate of the heart remained the same, it is evident that the output per unit of time would also be increased. But the slowing of the heart tends to reduce the total output; hence only cardiometer records can show which of these opposing factors prevail. As a matter of fact, Cushny found that the output of the heart per unit of time (*e.g.*, in a minute) was uniformly increased by small doses of digitalis; this increase amounted at times to fifty per cent. With somewhat larger doses the inhibitory action may become extreme and now the output is diminished. The output is increased again when the heart becomes more rapid.

During all the early part of the first stage the rhythm of the heart is normal; each beat of the auricles is followed by one of the ventricles, and the two sides of the heart beat together. If the drug is pushed the slowing becomes extreme and, as always happens when the vagus is strongly stimulated, the rhythm is disturbed. The muscular action may be entirely concealed by the inhibitory action so that the systoles become weaker and less blood is expelled; as a rule, however, the output per beat is still greater than normal while that per unit of time is less owing to the slow rate of the heart. The auriculo-ventricular beat may be more or less dissociated and the two chambers beat at different rhythms. Sometimes this is due to the excessive inhibition preventing the impulses from the auricle reaching the ventricle, a "block" being formed between the two chambers. At the same time the irritability of the ventricular muscle may be so increased that the ventricle assumes a rhythm entirely independent of the auricle; this "idio-ventricular" rhythm may be more rapid or slower than that of the auricle (see Fig. 1143). These changes in the rhythm of the heart always indicate a grave condition of poisoning and are not met with in the therapeutic use of digitalis.

During the second stage of the action of digitalis the muscular prevails over the inhibitory action. The pulse becomes very rapid, the inhibitory nerves no longer being able to keep the heart in check. The auricles are often later in being accelerated than the ventricles because the inhibitory nerves have a greater influence over them. The difference in rhythm of the two divisions leads to very characteristic variations in the strength of the contractions of both auricles and ventricles. Numerous other forms of irregularities occur which it is impossible

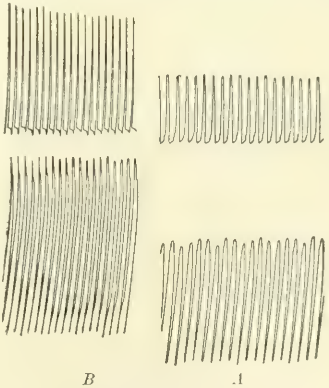

FIG. 1142.—Tracings of the Movements of the Ventricle (Lower) and Auricle (Upper) under Digitalis. During systole the levers make an up-stroke. In this experiment the inhibitory terminations had been paralyzed, so that only the muscular action is developed. *A*, Normal; *B*, after digitalis. The rhythm of the heart is slightly accelerated in *B*, and the levers extend further upward, indicating a more perfect systole in both auricle and ventricle. The ventricular lever does not reach so far downward in *B*, *i.e.*, the ventricular diastole is less complete. (From Cushny.)

to describe in a few words. They have many points of resemblance to those described under aconitine and can all be traced to the increased irritability of the cardiac muscle and to the interference of the (independent) auricular and ventricular rhythms. (For detailed accounts of these irregularities, which are of toxicological rather than of pharmacological interest, see the elaborate descriptions of Cushny, Knoll [*Sitzb. der Wiener Akad.*, xcix., Abth. iii., p. 31, 1890, and ciii., Sitz. November 8th, 1894], and François-Franck.) Many of the forms of irregularity can be imitated in the normal animal by electrical stimulation of different parts of the heart (see Cushny, *Journal of Physiology*, xxv., p. 49, 1899). Stimulation of the accelerators or of the vagi will often cause the most irregular heart to become regular again, and there is some evidence that the tonic activity of the accelerators is an important factor in counteracting the tendency of the heart to become irregular from digitalis.

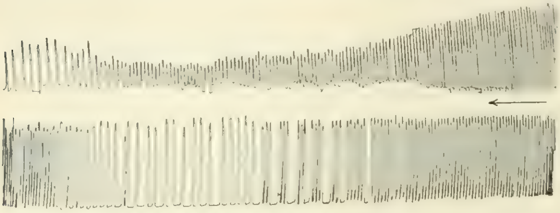

FIG. 1143. - Tracing of the Auricular (Upper) and Ventricular Movements (Lower) under Digitalis, as the First Stage Passes into the Second. During systole the levers move upward, during diastole downward. The rhythm of the two chambers is at first the same, but soon changes, the auricle maintaining its rapid beat, while the ventricle becomes slow and irregular. At the end of the tracing the ventricle again becomes rapid, while the auricles become slow. The strength of the contractions and the extent of relaxation of the ventricular muscle remain little altered, while the auricle rapidly weakens in strength, but improves again at the end of the tracing. (From Cushny.)

Eventually the heart passes into delirium cordis owing to the excessive stimulation of the cardiac muscle. After death the mammalian heart is found widely dilated in diastole, not contracted in systole as is the case with the frog's heart. Thus there seems to be a difference between the effects of digitalis upon the hearts of warm and of cold blooded animals—the former stopping in diastole, the latter in systole. François-Franck maintains, however, that this difference is only apparent; that the heart stops in systole in both cases, but that the mammalian heart is incapable of remaining long in this condition.

There has been considerable discussion as to whether the two halves of the heart are influenced alike by digitalis. Some have claimed that one ventricle was more powerfully stimulated than the other and that they at times beat at entirely different rhythms. Later writers, using more exact methods, have failed altogether to confirm these results. The auriculo-ventricular rhythm may be disturbed but the two aruricles and the two ventricles always beat at the same rate, although variations in the strength of the beat may occur in one chamber independently of the other.

Experiments upon the isolated mammalian heart give results in entire accord with those obtained by Cushny upon the heart in connection with the nervous and vascular systems. Tschistowitsch (*Centralbl. für Physiol.*, i., p. 133, 1887) showed, several years ago, that helleborein stimulates the isolated heart and increases its output per unit of time. Recently Hedbom (*Skand. Archiv für Physiol.*, viii., p. 185, 1898) has described in detail the action of digitalin upon the isolated rabbit heart. Immediately after the drug reached the heart there was a slight acceleration, just as we have seen to be the case when digitalin is applied to the frog heart. This primary acceleration was followed by a long-continued slowing during which, however, the amplitude of the beats was much increased. If the heart had from any cause become irregular, small doses of digitalin caused it to become more regular as well as more powerful. If the amount of digitalin was increased, the heart beat became rapid and the various kinds of irregularities described by Cushny were produced; then there was a sudden shortening of the ventricle (amounting in some cases to fourteen per cent. of its length) and the heart soon stood still. Bock (*Archiv für exper. Path. und Pharmakol.*, xli., p. 175, 1898) studied the action of helleborein upon the isolated mammalian heart, using a method differing in some respects from that of Hedbom; the results were, however, essentially the same. Bock emphasizes especially the rise of pressure which occurred in the tubes by which the peripheral vessels were replaced in his experiments and which resulted from the increased output of the heart. In one experiment in which the heart had been beating feebly, helleborein caused the pressure to rise from 29 mm. to 80 mm. of mercury—a striking example of the power of the drug to stimulate the cardiac muscle.

To sum up the results of these experiments upon the heart, digitalis in small doses slows the heart, but its chief action is to increase the contraction in systole. This increased contraction leads to a more complete emptying of the ventricle and so to a greater output of the heart and a rise of blood pressure. In the normal animal, with perfect valves, and in which there is no dilatation of the heart, constriction of the arterioles caused by the direct action of the drug upon their walls is probably as important a factor in the rise of blood pressure as is the increased output of the heart. But experiments upon animals have shown that the increased output of the heart is especially marked when there is even a slight dilatation of the heart; and the experiments of Bock show what a marked rise of pressure may be produced by the cardiac action alone. When it comes to certain cases of chronic valvular lesions in man in which the dilatation is far in excess of anything we ever have in experiments upon animals, we are justified in concluding that the cardiac action of the drug is by far the most important factor in the rise of blood pressure which undoubtedly occurs. The heart action of digitalis also has a different effect upon the pressure in the veins in cases of valvular insufficiency from its effect in normal animals. In the latter mere increase in the output of the heart is powerless to lower the venous pressure and so relieve venous congestion; only a constriction of the arterioles can bring this about. With incompetent valves, however, the greater contraction of the cardiac muscle caused by digitalis will lessen the regurgitation and so the backward pressure in the veins; this leads to a fall of venous pressure and so to a lessening of venous congestion. The constriction of the arterioles caused by digitalis will add to this result, but the cardiac action alone is often sufficient.

Too much emphasis is sometimes laid upon what are, after all, but minor features of the action of digitalis—the slowing of the heart and the constriction of the arterioles. Both of these actions are undoubtedly important in many, perhaps in most cases, but they are entirely subordinate to the action upon the cardiac muscle. Aconitine or veratrum viride will cause as great a slowing of the heart as will digitalis; strychnine or the extract of the suprarenal glands will constrict the vessels even more strongly, but none of these drugs or any combination of them can replace digitalis.

So far we have spoken of the action of "digitalis," ignoring the fact that several active principles are contained in the usual preparations. Our knowledge of the active principles is, however, so unsatisfactory and the isolation of some of them is attended with such difficulty and expense that they are not used very extensively in medicine. Schmiedeberg (*Archiv für exper. Path. und Pharmakol.*, iii., p. 19, 1874) described three active principles in digitalis and named them digitalin, digitalein, and digitoxin. Kiliani (*Archiv der Pharmacie*, 1892-99) has published a series of papers in the earlier of which he stated that the digitalein of Schmiedeberg was probably a mixture of digitalin and some inert substance; he also described a new glucoside occurring in the leaves which he named digitophyllin. According to these earlier investigations of Kiliani the leaves, from which the pharmacopœial preparations are made, contain three glucosides, digitoxin, digitophyllin, and a body resembling digitalin; digitalin itself is probably absent. All of these glucosides have a similar action, but digitoxin seemed to be the most abundant and was found to be by far the most active. In fact digitoxin is one of the most toxic substances known. From these investigations of Kiliani it seemed that the pharmacopœial preparations owed their activity largely to digitoxin, although the almost complete insolubility of this body in water and its extremely irritating properties made it difficult for some to accept this view. Very recently Kiliani (*Archiv der Pharmacie*, ccxxxviii., p. 464, 1899) has confirmed the old statement of Schmiedeberg that there is a distinct body, digitalein, easily soluble in water and which occurs in both the seeds and leaves. Böhm (quoted by Kiliani, *loc. cit.*) believes that the activity of the infusion is due very largely to this digitalein. This work is so recent that no experiments seem to have been made to determine to what extent digitalein can be used instead of the galenic preparations. Experiments had already indicated that neither digitalin nor digitoxin could entirely replace the tincture and infusion in therapeutics.

A very large number of other plants contain substances with a physiological action very like that of digitalis. A few of these are used in medicine, while others are of interest chiefly because they have been used as arrow or ordeal poisons. It is known that there are minor differences between the action of some of these substances and that of digitalis; some, for example, have a greater effect upon the heart and a less effect upon the blood-vessels, others stimulate the vagus centre very powerfully, etc. Few comparative studies have been made, however, although they are extremely desirable.

Some of the other members of this series will be mentioned, and the points in which their action differs from that of digitalis noted when this is known. Strophanthus hispidus and S. Kombé contain a body, strophanthin, which is usually considered to be a glucoside. Strophanthin acts as powerfully upon the heart as does digitalis but has less effect in constricting the vessels; it does not cause as great a rise of pressure in the pulmonary artery as does digitalis. Erythrophlœin (a glucosidal alkaloid, derived from Erythrophlœum, sassy or casca bark) seems to act less upon the cardiac muscle and more upon the vagus centre than the others. Squills contains a glucoside, scillain, about which very little is known. Preparations of squills act upon the heart like digitalis, but they are used less for this action than for their action as expectorants and diuretics; it is very probable, however, that their cardiac action is an important factor in bringing about the changes in the respiratory mucous membrane and in the kidneys, for the circulation through these parts is improved by the drug. Helleborein (the glucoside found in Helleborus niger) and convallamarin (derived from the lily of the valley) are both very soluble in water, and it was hoped that they might prove valuable remedies when it was desired to use pure substances. Extended observations have shown them to be unreliable, and when they are used at all it is in the form of the galenic preparations. Euonymin (from Euonymus atropurpureus, wahoo) is used as a purgative rather than as a cardiac stimulant.

Some of the other substances belonging to this series are apocynein (from Apocynum cannabinum, Canadian hemp), adonidin (from Adonis vernalis, pheasant's eye), antiarin (from Antiaris toxicaria, the upas tree), one of the most powerful substances of the series; neriin and neriodorin (to which the poisonous properties of nerium or the oleander are partly due), thevetin and cerberin (from thevetia), coronillin (from coronilla) and tanghinin (from Tanghinia venenifera). The arrow poisons quabain and echujin also belong to this series.

The skins of certain toads were formerly used as remedies for dropsy. Modern investigations have shown them to contain a poison, phrynin, which has an action upon the heart very similar to that of digitalis. Epinephrin, the active principle of the suprarenal glands, also resembles digitalis in some of its physiological properties. The salts of barium have an action upon the heart and blood-vessels similar in many respects to that of the digitalis series.

For a discussion of the use of these drugs in therapeutics the reader is referred to the articles on *Heart Diseases;* only a few of the more general indications for their use can be given here. It has been shown that the circulation is influenced in three principal ways by medicinal doses of digitalis: the pulse is slowed, the heart contracts more completly in systole so that the pulse volume is increased, and the peripheral arterioles are constricted. Of these the second action is by far the most important in therapeutics. The action of digitalis in slowing the heart is taken advantage of in treating some cases of palpitation, of "irritable heart," and in a number of other cases, as in certain stages of valvular diseases, acute febrile conditions, etc., in which the heart is beating feebly, but rapidly and irregularly. On the other hand, the slowing of the heart is in some cases an undesirable feature of the action of digitalis, for, as has been already shown, it is due to a stimulation of the inhibitory nerves, and the latter has an effect just the opposite of the action of the drug upon the cardiac muscle. It is the inhibitory action which often prevents an increase in the contraction of the auricle; in fact, a diminution of the force of the auricular contraction is often observed. The same effect is produced upon the ventricle, but here the muscular action is able to overcome the inhibitory action to such an extent that the latter is not usually a disturbing element. A drug in which the muscular action of digitalis was well marked while the inhibitory action was minimal, would doubtless be much more valuable in many cases than digitalis. In erythrophlœin the inhibitory action is well developed while the muscular action is but little marked; unfortunately no drug is at present known in which the opposite is the case.

The constriction of the arterioles by digitalis is in many cases a desirable feature of its action, for by it the general blood pressure is raised and the blood accumulates in the arteries and excessive venous pressure is relieved. The constriction of the arterioles seems to be a factor in the production of diuresis; at least strophanthin which does not have so marked an effect upon the arterioles causes much less diuresis than does digitalis. In many cases, on the other hand, it has been found desirable to counteract the effect of digitalis upon the arteries while retaining its action upon the heart. This result is obtained by combining the digitalis with some drug (usually a member of the nitrite group) which causes a dilatation of the peripheral vessels; or the difficulty may be got around by the use of strophanthin, which does not constrict the vessels very greatly.

It is in virtue of its action upon the cardiac muscle that digitalis is chiefly used in medicine and by which it is enabled to play a rôle which can be filled by no other substance. Dilatation of the heart from almost any cause, provided that extensive degeneration of the cardiac muscle is not present, is the indication for its use. In such a case the action is very simple and is almost specific. In dilatation the heart is not only abnormally relaxed in diastole, but the amount of blood remaining at the end of systole is greatly increased. Digitalis causes a more complete emptying of the ventricle, *i.e.*, the pulse volume is increased; this and the constriction of the arterioles lead to a higher blood pressure and a more uniform flow through the capillaries. Venous congestion is relieved and the nutrition of the various organs, including the heart, is improved. At the same time the relaxation in diastole is usually lessened so that the heart assumes more nearly its normal form. It is especially in dilatation in cases of valvular disease that digitalis is used; in such cases in addition to the above action the drug causes a contraction of the ring of muscle surrounding the diseased valve, and this tends to limit the regurgitation. As a result of the increased work of the heart and its better nutrition the condition of the muscular tissue is improved to such an extent that after a time the drug can often be dispensed with for longer or shorter periods.

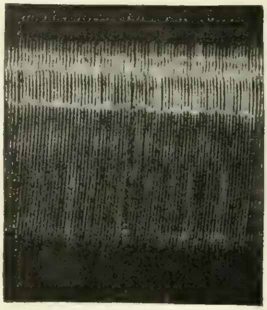

Fig. 1144.

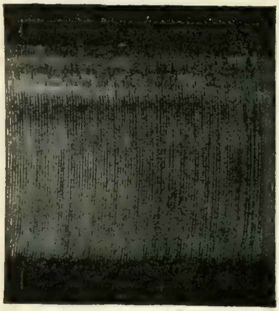

Fig. 1145.

Figs. 1144 and 1145. Tracing of the Ventricle of the Dog's Heart: 1144, Normal; 1145, After Caffeine. The lever moves upward during systole, downward during diastole. The only alteration caused by caffeine is acceleration. The slightly larger excursion in diastole in 1145 is mechanical. (Contrast tracings under digitalis: Figs. 1141 and 1142.) (From Cushny.)

The question is often debated whether digitalis should be used in aortic insufficiency; the theoretical objection has been made that the prolonged diastole might allow time for sufficient blood to regurgitate to lead to syncope. Physicians seem to hold now that digitalis is just as serviceable in the dilatation accompanying aortic insufficiency as in other cases, provided it is given with care. A little experiment of Dreser's (*Archiv für exper. Path. und Pharmakol.*, xxiv., p. 238, 1888) may be mentioned in this connection. The valves of the ventricle of a frog's heart were destroyed, the ventricle was tied to a perfusion cannula on one limb of which was an outflow tube. This arrangement represented roughly the condition in aortic insufficiency; the pressure of the liquid in the upright tube represented the aortic pressure, while the side tube, from which the blood was collected, represented the peripheral circulation. Blood was led to the heart and the amount expelled from the side tube measured. Digitalis (or helleborein) was now added to the blood; the heart was slowed so that there was a greater opportunity for the blood to drain back through the broken valves into the ventricle, and if the above theory were correct the outflow from the side tube (*i.e.*, the peripheral circulation) should be diminished. Dreser found, on the contrary, the outflow to be uniformly much increased; the increased output of the ventricle and the prolonged systole had more than counteracted the effect of the prolonged diastole. This little experiment is of interest as it shows that the only experimental evidence we have agrees with the clinical evidence that digitalis is useful in aortic insufficiency.

Members of the digitalis series are used for other purposes than as cardiac tonics, although the heart action probably plays a more important part here than is always recognized. Thus the good results following the use of squills as an expectorant are almost certainly due in part to an improvement of the pulmonary circulation. Several of the series are used extensively as diuretics; the fact that as a rule they produce marked diuresis only when there is a diseased condition of the heart points to the effect upon the kidney being secondary to changes in the circulation. On the other hand some of these drugs produce diuresis in normal rabbits, and occasionally in healthy dogs and man, when there is no evidence that the renal circulation is altered; this indicates that some of the series, especially squills and digitalis, have a direct action upon the renal epithelium, but comparatively little satisfactory work has been done upon this subject. There can be little doubt that the extraordinary diuresis produced by digitalis in cases of cardiac dropsy is due largely to an improvement in the renal circulation; the blood is removed from the veins and collected into the arteries, the congestion of the kidney relieved and a more uniform and active circulation established—a condition favorable for the secretion of the urine.

Sparteine, the alkaloid of broom (Cytisus scoparius), has been included by some in the class of cardiac stimulants. It has been said to have an action similar to that of digitalis; recent work (Cushny and Matthews, *Archiv für exper. Path. und Pharmakol.*, xxxv., p. 129, 1895) has shown this resemblance to be entirely superficial and that the drugs have little in common. Broom is used to some extent as a diuretic in cardiac diseases; it is also said to make the heart beat more regularly.

Cactus grandiflorus (cereus) has been warmly recommended by some clinicians as a cardiac stimulant. Very little is known about the chemistry of this drug or its physiological action; there is certainly no evidence that it belongs to the digitalis series, as has been claimed by some. It is said to accelerate the heart and to cause a rise of blood pressure; the latter seems to be due in part to a stimulation of the vaso-motor centre. It is sometimes combined with digitalis, but is said to be especially useful in certain cases in which digitalis is contraindicated. It is said to be valuable in cardiac weakness due to tea, coffee, alcohol, tobacco, etc.

Caffeine.—Caffeine has a very characteristic action upon cardiac muscle which makes it a cardiac stimulant of great value in some cases; it has also a stimulating action upon the vaso-motor and other medullary centres. The changes in the cardiac muscle have been most carefully studied in the frog's heart. When blood containing minute quantities of caffeine is perfused through a frog's heart placed in a William's heart apparatus, the rate of the heart is slightly accelerated and the amount of blood expelled at each beat slightly increased, but the most marked change is an increase in the force of the beat (Dreser, *Archiv für exper. Path. und Pharmakol.*, xxiv., p. 233, 1888). The heart is able to contract against a much greater aortic pressure than normally—that is, the "absolute power" of the cardiac muscle is increased. Dreser compares this action of caffeine to an increase in the cross section of the muscle fibres while their length remains the same. Caffeine has thus an action entirely different from that of digitalis; the effect of the latter is the same as lengthening the muscle fibres while the cross area remains the same; the extent of the contraction under digitalis is increased, while the absolute force is scarcely altered.

After larger quantities of the drug the heart becomes slower and its volume smaller; then the apex ceases to relax with the rest of the ventricle, but remains white and contracted, and eventually the whole heart passes into a condition of rigor. In all these respects the action of caffeine upon the cardiac muscle is very similar to the remarkable effects the drug is known to have upon ordinary skeletal muscle.

Upon the mammalian heart the chief effect of caffeine which has been described is an acceleration of the rate: this acceleration occurs when the heart is entirely isolated from the central nervous system (Bock, *Archiv für exper. Path. und Pharmakol.*, xliii., p. 367, 1900), and must therefore be attributed to a stimulation of the cardiac muscle. No observations seem to have been made upon the effect of caffeine on the absolute power of the mammalian heart; that the extent of the contractions, and so the pulse volume, is not increased is shown by the accompanying myocardiograms (Figs. 1144 and 1145).

When caffeine is administered to a normal animal the effects upon the heart are somewhat obscured by the simultaneous action upon certain nerve centres. As a rule the heart is accelerated, but at times it is slightly slowed by a stimulation of the centre of the cardio-inhibitory nerves. On the other hand, stimulation of the vagi is usually less effective in slowing the heart after caffeine owing to the increased irritability of the cardiac muscle. That the cardiac acceleration is not due to a paralysis of the terminations of the vagi is shown by the fact that it occurs after these have been paralyzed by atropine; the acceleration must be attributed to a direct stimulation of the heart muscle. After larger doses the heart becomes weak, irregular, and arhythmic, resembling the condition seen in digitalis poisoning. The vaso-constrictor centre is stimulated by caffeine: this and the increased output of the heart due to the acceleration cause a rise of blood pressure. The most marked effects upon the circulation are seen in animals in which this has been depressed by such a drug as alcohol. Thus Binz found that the blood pressure of a dog deeply under the influence of alcohol rose from 84 to 120 mm. in ten minutes after the subcutaneous injection of caffeine; the pulse rate was doubled. The respiration was also greatly improved.

Administered to a healthy man a moderate dose of caffeine causes the pulse to become full and hard; it is also moderately accelerated. Occasionally there is a slowing due to stimulation of the vagi.

Theobromine has an action upon the heart very similar to that of caffeine; the peripheral vessels are not constricted, however, and so the rise of blood pressure is much less marked.

The great diuretic power of caffeine has been attributed to the changes in the circulation, and it is probable that these do exert a favorable influence when the blood pressure is very low. Under ordinary circumstances, however, the constriction of the blood-vessels antagonizes the diuretic action, and the latter can often be obtained only when the caffeine is combined with such drugs as chloral hydrate or paraldehyde which dilate the vessels. It is now generally held that caffeine and theobromine produce diuresis by a direct action upon the renal epithelium, and entirely independent of their action upon the circulation.

The experiments upon animals indicate the class of cases in which caffeine might be expected to give good results in therapeutics. It is chiefly in cases in which the heart is simply weak and in which there is no dilatation that caffeine is indicated; it causes the output of the heart to be increased and the blood pressure to rise. It is especially useful in cases of alcoholic and opium poisoning, for not only is the cardiac muscle stimulated in these, but the vaso-motor and respiratory centres are also thrown into increased activity. Caffeine cannot be considered a substitute for digitalis, for it has almost no effect upon dilatation of the heart in valvular lesions; it is often used in such cases, either alone or combined with digitalis, but the beneficial results seem to be due much more to its diuretic than to its cardiac action.

Strychnine.—Strychnine has come into somewhat extensive use in recent years as a cardiac stimulant; the good results following its use are probably to be attributed to its action upon certain parts of the central nervous system (especially the vaso-motor centre) and the nutrition generally, rather than to any special action upon the heart. At the same time there is some evidence that the frog's heart is directly stimulated by small quantities of strychnine while larger amounts weaken and slow it. In the mammal strychnine causes a slight slowing of the heart due to stimulation of the vagus centre. If convulsions occur, the heart becomes accelerated just as it does in struggling from any cause. Few drugs have such a powerful action upon the vaso-constrictor centre as has strychnine. Whether convulsions occur or not the arterioles are constricted to an extreme degree and the blood pressure rises enormously. The irritability of the subsidiary vaso-motor centres in the spinal cord is increased, so that a reflex rise of blood pressure may follow stimulation of a sensory nerve after the influence of the chief vaso-constrictor centre has been removed by section of the cervical cord.

Strychnine, like iron, seems to be used rather as an adjuvant to digitalis in the treatment of heart diseases; at the same time it is frequently recommended in those cases in which digitalis is contraindicated. It is also used in cardiac failure during typhoid and other fevers, shock, etc.; in these cases the action is probably mainly upon the vaso-motor centre. *Reid Hunt.*

CARDIOGRAPHY. See *Heart.*

CARLSBAD (Karlsbad) is one of the most important thermal stations of Europe; indeed, its reputation is world-wide. It is charmingly situated in the northwestern corner of Bohemia, some 70 miles from Prague, at an altitude of about 1,160 feet, lying in the narrow valley of the Tepel River among the pine- and fir- clad hills traversed by paths in all directions. There are many beautiful walks and drives in the woods covering the slopes of the valley, and attractive excursions in the environs. "The valley in which it lies is shielded from the south and east winds by the mountains, but is exposed to the winds from the north and west, and the climate is consequently somewhat trying and subject to sudden changes in temperature" (Stedman). The native population is about 12,000, and upward of 30,000 people visit the springs annually.

These thermal waters are said to have been discovered in 1347, by the Emperor Charles IV., while hunting, but Carlsbad was known as a health resort a century earlier (Baedeker). "The springs issue from apertures in the rocky shell upon which most of the town is built, and are sixteen in number, all similar in their ingredients, which are principally sulphate of sodium, carbonate of sodium, and common salt. They are chiefly taken internally. They vary in temperature, the hottest having the least amount of carbonic acid gas. Some of the principal springs are the following (with their temperatures, Fahrenheit scale):

"Sprudel, 162.5°—a steaming fountain leaping up at short intervals, and having a capacity of four hundred and fifty gallons per minute; Felsenquelle, 138°; Schlossbrunnen, 127°; Mühlbrunnen, 124.5°; Theresienbrunnen, 122°; Marktbrunnen, 118°. These waters are classed among the sulphated alkaline waters." The following is the composition of the Sprudel water, according to the analysis of Ragsky, as given by Stedman. "Each litre (1.76 pint) contains:

	Grams.		Grains.
Sulphate of sodium	2.372	=	35.58
Sulphate of calcium	.163	=	2.44
Chloride of sodium	1.030	=	15.45
Carbonate of sodium	1.361	=	20.41
Carbonate of calcium	.297	=	4.45
Carbonate of magnesium	.124	=	1.86
Carbonate of strontium	.0008	=	.012
Protoxide of iron	.002	=	.03
Protoxide of manganese	.0006	=	.009
Fluoride of calcium	.003	=	.045
Phosphate of calcium	.0002	=	.003
Silica	.0072	=	.108

Carbonic acid in one litre 210.59 c.c." (Stedman).

Although, as has been said, the waters are now used chiefly internally, there are seven bath houses with mineral, mud, vapor, hot air, and other baths, and with massage and Swedish movements. The Kaiserbad is said to be "one of the most magnificent bath houses of Europe." The conditions for which the internal use of Carlsbad water is beneficial are stated by Weber to be the following:

In the first place, affections of the liver, including catarrhal jaundice, frequent attacks of biliary colic, early stages of alcoholic cirrhosis, enlargement of the liver in great eaters, etc. Secondly, habitual constipation, hemorrhoidal conditions in robust persons, some cases of chronic gastric and intestinal catarrh with or without diarrhœa, some cases of dyspepsia, uric-acid diathesis, chronic glycosuria in fat people, and corpulence, which is often combined with a weak-acting heart. Enlargement of the spleen is also said to be benefited by these waters, as are also periodic, frequently recurring headaches connected with abdominal disorders. Disturbances of the female pelvic organs, chronic congestion and enlargement of the uterus, chronic affections of the conjunctiva and deeper structures of the eye, and chronic aural catarrh are all likely to be benefited or cured by the Carlsbad waters (Stedman).

During the summer the usual time for drinking the waters is from half-past five to half-past eight in the morning, an interval of about a quarter of an hour being allowed after each glass (℥ vi.), and the dose being from two to six glassfuls.

In beginning a course of treatment the spa physician carefully considers each case, and regulates the habits and diet of the patient. Probably the regularity in daily life and diet has very much to do with the improvement of the patient. The average daily programme of the ordinary Kurgäste is outlined by Weber as follows:

"Rise early to drink the water, and in the intervals promenade to the sound of the music; walk to some café, and take breakfast at about 9 A.M., consisting of coffee or tea, rolls, and perhaps boiled eggs or ham. At about one o'clock the chief meal of the day is taken; coffee and tea at about 4 P.M., and a light supper in the evening." Those who have been ordered a course of baths mostly take them in the forenoon. There are a fine Curhaus and a good theatre; classical concerts are given regularly; there are covered walks; in brief, there is almost everything which will render the stay of the invalid agreeable and pleasant. There are also good educational facilities.

The season lasts from the middle of April to the end of September or October, although one can take the waters at any season of the year. Besides the amount of water drunk at Carlsbad, it is said that about 3,000,000 bottles and 110,000 pounds of the salt are exported annually.

An after-cure is always recommended subsequent to a course at Carlsbad. Instead of returning home immediately, and at once resuming his or her usual mode of life, the patient should abstain from active work, adopt a simple diet, and live outdoors as much as possible for some weeks.

Carlsbad is reached by various routes in about thirty-one hours (from London): by Cologne, Würzburg, and Nürnberg or Bamberg; by Paris, Stuttgart, and Nürnberg; or by Cologne, Leipsic, Dresden, and Kromotan.

For the major part of the above account of Carlsbad, the writer is indebted to "Spas and Mineral Waters of Europe" (by Hermann and F. Parkes Weber, London, 1896), to which the reader is referred for much valuable information upon this subject. *Edward O. Otis.*

CARMINE. See *Cochineal.*

CAROBA.—A name applied to the leaflets of several species of *Jacaranda* (fam. *Bignoniaceæ*), small trees of Brazil, especially of *J. procera* (Willd.) Spreng. and *J. Caroba* (Vell.) D. C. They contain resinous and slightly aromatic constituents, and the crystalline, apparently insective body *carobin*, but nothing to which any special medicinal properties can be assigned. The drug bears a high reputation and is largely used in Brazil as a remedy for syphilis and syphilitic disorders. This belief, which applies to so many plants of little or no activity, doubtless results from the indefinite ideas which prevail regarding syphilis, all sorts of venereal diseases being included under this name. The drug is generally given in the form of the fluid extract, in doses of 1 to 4 c.c. (♏xv. to lx.).

Henry H. Rusby.

CAROTA.—*Carrot.* The root of *Daucus carota* L. (fam. *Umbelliferæ*). This plant is a native of Europe, but freely naturalized in the United States (wild carrot). The cultivated form is the common table carrot, grown everywhere. The fruits of wild carrot have been used as aromatic diuretics; the cultivated roots are made into pulp as poultices; but neither have any claim to medical notice. The coloring matter of carrot root is called *carotin.* The very small amount of volatile oil consists of pinene and probably cineol. *W. P. Bolles.*

CARTHAGENE BARK.—See *Cinchona.*

CARTHAMUS. See *Safflower.*

CARTILAGE.—Under this name is classified one of the important members of the group of connective tissues; it is characterized not so much by the structure and arrangement of its cells, as by the peculiar nature of its basement substance. Cartilage occurs in three tolerably distinct forms, the differences of which depend largely upon peculiarities in the structure of the basement substance. These forms are called *hyaline cartilage, fibro-cartilage*, and *fibro-elastic cartilage.*

The most abundant and typical of these is *hyaline cartilage.* This, in the adult, is found covering the articular surfaces of bone, forming parts of the ribs and of the walls of the trachea and bronchi, and in less considerable masses in other parts of the body. Hyaline cartilage is translucent and of a bluish-white color, is firm in consistency, and elastic. Like other members of the connective-tissue group, it consists of cells and an intercellular or basement substance. The basement substance is for the most part quite homogeneous in the fresh condition, but it is occasionally very finely granular. By suitable treatment with chemical agents, it may be seen to contain, and almost to consist of, exceedingly minute and delicate fibrils, which under normal conditions are merged into a homogeneous mass. The basement substance is said by some observers to be penetrated by minute branching canals which communicate with one another and with the spaces in which the cells lie. Mucin and gelatin, and a rather indefinite substance called chondrin, have been obtained from the basement substance, but our knowledge of the chemical nature of these substances, and particularly of their existence in the cartilage in the natural condition before being exposed to chemical manipulation, is still too indefinite to enable us to speak very positively of its chemical constitution.

The cells of hyaline cartilage differ considerably in shape and arrangement in different cartilages and in different parts of the same cartilage, depending, apparently, to a considerable degree, upon the conditions of pressure to which they are subject, as well as upon the intimate constitution of the basement substance and the influences under which its development transpires. The cells, except near free surfaces or where cartilage and fibrous tissue join, are in general spheroidal, ovoidal, ellipsoidal, or somewhat flattened at the sides, and lie unevenly distributed in the basement substance. The cell body is finely granular, or in some animals contains delicate fibrils, or may enclose droplets of fat, and pigment particles, or may also contain glycogen. The nuclei—of which there may be one or more—are usually spheroidal, sharply outlined, and contain more or less well-marked networks of coarser and finer fibrils and nuclei, in which, during life, in some animals, slow oscillatory movements may be seen. The cartilage cells may lie singly in the basement substance, but they are more frequently arranged in groups of two or four, or more, and the cells forming these groups are apt to be flattened on the sides which abut on one another. Under normal conditions the cartilage cells completely fill the spaces in the basement substance in which they lie. But on exposure to the air, to water, to electric shocks of moderate intensity, to a variety of chemical agents, and under certain pathological conditions, they separate from the walls of the spaces and shrink into irregular-shaped, coarsely granular masses, in which the nucleus may be partially or entirely concealed. This shrinkage may be only partial, some portion or points remaining adherent to the sides of the cavities, so that the shrunken cells may appear irregularly stellate or have festooned edges. In this shrunken condition we usually see the cells of cartilages which have been preserved in alcoholic fluids. In some parts of the articular, and also in the costal cartilages, the cells lie in large groups, or in longer or shorter rows. At the free surfaces of cartilage, or where it comes in contact with the perichondrium, the cartilage cells are usually flattened, and just beneath the perichondrium may merge imperceptibly into the ordinary flattened cells of the connective tissue. The basement substance immediately about the cartilage cells may be seen, under favorable conditions, to be more transparent than the rest, the more transparent zone being sometimes very thin and sometimes of considerable thickness. This portion of the basement substance is called the capsule, and is believed to be that part which was last formed around the cartilage cell. Somewhat similar appearances may be seen not only around single cells, but around all groups which have apparently been derived from some single cell originally occupying their position in the basement substance.

The basement substance of hyaline cartilage may, under a variety of conditions, become infiltrated with salts of lime, and thus assume to the naked eye a white, opaque appearance, and under the microscope appear crowded with larger and smaller distinct granules. Under pathological conditions the basement substance may become fibrillar as well as calcified. Cartilage is surrounded, except over the articular surfaces, by a vascular layer of fibrillar connective tissue called the *perichondrium*. The perichondrium contains a varying amount of elastic fibres. The fibrillated fibres of the perichondrium pass on into the hyaline basement substance of the cartilage, into which they become gradually merged. Although vessels from the perichondrium sometimes penetrate for a short distance into the cartilage tissue, the latter is, in general, non-vascular.

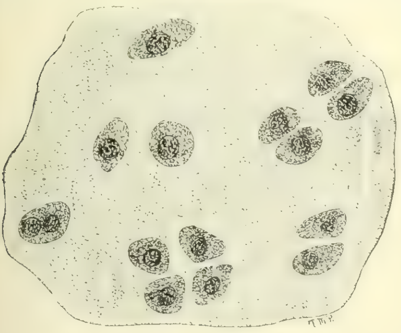

FIG. 1146.—Hyaline Cartilage from the Head of the Femur of Frog. (× 700 and reduced.)

DEVELOPMENT OF HYALINE CARTILAGE.—At a very early period hyaline cartilage consists of a congeries of rounded cells closely packed together, with a small amount of intercellular substance around each cell. The intercellular substance gradually increases in amount, and the cells divide; new capsules, *i.e.*, new portions of intercellular substance, are formed around the new cells, while the old capsules are expanded and appear to coalesce with those of adjacent cell groups to form the homogeneous basement substance. In this way the cells become gradually separated from one another, but may still retain a grouping which indicates their primitive relations.

Schleicher has shown that in the division of cartilage cells, while the changes in the nucleus are in general those common to the indirect mode of cell division (see *Cell*), the separation of the body occurs, not by a gradually deepening constriction as in cells which are surrounded by a fluid or yielding material, but by the formation of a partition out of the intracellular filaments. This partition finally becomes continuous with the capsule around the new-formed cells, and thickens with their separation from one another. The exact way in which the capsules and intercellular substance originate, whether by a separation of a portion of the periphery of the cells, or whether it is simply formed under their influence, or entirely apart from them, is not certain.

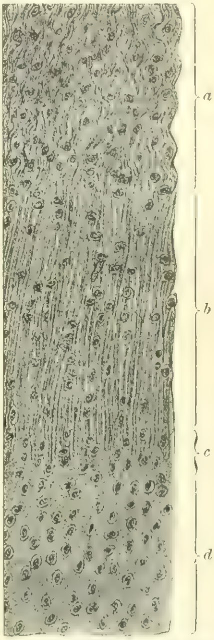

FIG. 1147. White Fibro-Cartilage from the Ligamentum Teres at the Point where it is Inserted into the Head of Femur. × 650 diameters. (After Böhm and Davidoff.) *a*, Fibrous connective tissue; *b*, fibro-cartilage; *c*, point of insertion of the ligamentum teres; *d*, hyaline cartilage.

FIBRO-CARTILAGE.—This variety of cartilage is found in the interarticular cartilages of some of the joints, such as the knee and jaw, between the vertebræ, at the symphysis pubis, around the tendons of certain muscles, and at points where tendons are inserted into hyaline cartilage, as at the junction of the ligamentum teres with the head of the femur. The cells are similar to those of hyaline cartilage, but the basement substance is fibrillated, the fibrillæ being arranged in dense bundles or interlacing in all directions. The cells are frequently arranged in rows between the bundles of intercellular fibres (see Fig. 1147), and are less uniformly distributed than are the cells of hyaline cartilage. This form of cartilage frequently merges, in structure, on the one hand into fibrillar connective tissue, and on the other into hyaline cartilage.

FIBRO-ELASTIC CARTILAGE (yellow elastic or spongy cartilage).—This form of cartilage is not abundant in the body, being found in small masses in the external ear, Eustachian tube, epiglottis, and in some parts of the larynx. It is tough, opaque, and yellowish in appearance. The cells, which are irregularly distributed through the basement substance, are similar in appearance to those of hyaline cartilage. Around each cell is a narrow, strongly refractile, homogeneous zone of basement substance—the capsule. Outside of the capsule the basement substance is more or less densely filled with coarser and finer anastomosing and interlacing elastic fibres (Fig. 1148). In addition to the elastic fibres the basement substance contains numerous large and small granules, consisting of a material similar in chemical and optical properties to that composing the elastic fibres—the so-called elastic granules. These elastic granules are unevenly distributed through the basement substance. Fibro-elastic cartilage is developed from a hyaline form of cartilage by the formation, in the basement substance, of the characteristic elastic fibres and granules.

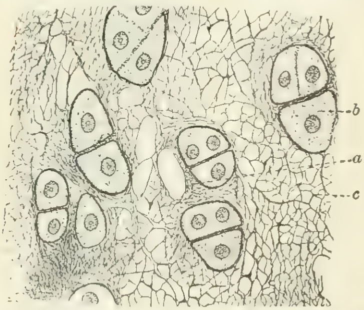

FIG. 1148. Elastic Cartilage from the Human Ear. × 760 diameters. (After Böhm and Davidoff.) At *a*, in the immediate vicinity of the cartilage capsules, a network of elastic fibres with fine meshes: *b*, cartilage cell; *c*, elastic fibres.

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For the methods of studying cartilage, see Ranvier's Traité technique d'Histologie, p. 270 *et seq.* For literature, see Index Catalogue of Library of Surgeon-General's Office, U. S. Army, vol. ii.; also Quain's Anatomy, tenth edition, vol. i., part ii., p. 244.

T. Mitchell Prudden.

CARVACROL.—*Oxycymol. Cymophenol.* ($C_6H_3.CH_3.[CH_2.CH_2.CH_3]6H$). This is one of the active constituents of oils of thyme and summer savory, and occurs also in some other plants. It is a thickish volatile liquid, with a specific gravity of about .981. It has a characteristic odor. Like thymol, with which it is associated, it is strongly antiseptic. It is very closely related to carvol, having the same composition.

Henry H. Rusby.

CASANTHROL is a thick and gelatinous emulsion of neutral reaction, composed of casein ointment and ten per cent. of lithanthracic extract. The latter consists of those constituents of coal tar which are soluble in benzol and ether. Casanthrol is soluble in water and when applied to the skin dries like a coat of varnish. However, being pervious to water, it does not prevent, but rather, if anything, tends to increase, the perspiration. It is precipitated by mineral acids, acid salts, and calcium salts; no oil separates from it on warming, and it does not become rancid. Classing it among his water-soluble varnishes Unna considers it a valuable application in chronic eczema and other chronic conditions of the skin.

S. Beck uses it in eczema and prurigo with no unpleasant secondary effects. It is the strongest coal-tar preparation which can be employed in inflammatory conditions of the skin; and if desired it may be used as a vehicle for other drugs. *W. A. Bastedo.*

CASCARA AMARGA.—*Honduras Bark.* The bark of *Picræna Vellozii* Engl. or of a related species, or, according to some authors, of an undetermined species of *Tariri*, syn. *Picramnia* (fam. *Simarubaceæ*). This bark comes from Central America, and is a very highly esteemed vegetable bitter by those who are accustomed to it. There is, with its strongly bitter taste, a peculiar sweet and aromatic flavor not resembled by any other drug. It contains a small amount, about one-half per cent., of volatile oil and about three per cent. of the alkaloid *picramnine.* The latter has the peculiar sweet and bitter taste of the bark and is probably its principal active constituent. It, as well as its salts, is amorphous. It is a simple or slightly aromatic bitter of unusually pleasant flavor. Its use as an alterative in syphilis is common, but we have no evidence of any special properties in this direction. The dose is .3 to 1 gm. (gr. v.–xv.).

Henry H. Rusby.

CASCARA SAGRADA.—*Rhamnus Purshiana.* Chittem Bark; Sacred Bark. "The bark of *Rhamnus Purshiana* D C. (fam. *Rhamnaceæ*)" (U. S. P.). To this definition should be added "collected at least a year before being used." The genus Rhamnus and the nature of its species and their constituents have already been discussed under *Buckthorn.* The species here considered is a small tree growing very abundantly in our extreme Northwestern States and northward. It was introduced into the materia medica in 1878 and encountered a remarkable degree of prejudice and opposition, being practically boycotted by many of the most influential physicians. It, however, steadily increased in favor and is at present probably the most largely used in professional practice of any American drug. During its early history, the bark of a related species, *R. Californica* Esch., growing abundantly in central and southern California, was frequently substituted for it, but persistent exposure resulted in completely stopping the fraudulent practice, so that adulteration and substitution are now almost entirely unknown. The bark is taken off in quills, but these are afterward broken up to save space in transportation. These quilled pieces are of variable thickness, up to nearly one-quarter of an inch. The outer surface is rarely fissured, but is more or less warty, the warts being low and broad. The surface is originally of a peculiar red-purple or purple-brown, but becomes more or less covered with gray lichens. These may grow so as to form a uniform gray covering or a series of gray patches of variable size. Pieces taken from the base or junction with the root, are frequently thrown into transverse wrinkles or semi-folds. The inner surface when fresh is light-yellow, but exposure turns it gradually darker until after two or three years it may be nearly black. The fracture is sharp and of a pale yellow. There is a slight odor and a peculiar bitter and somewhat aromatic taste. Preparations of the drug are apt to have a very disagreeable taste and numerous formulæ have been devised for avoiding this disagreeable feature.

COMPOSITION.—The composition of cascara sagrada is very similar to that of buckthorn in its general nature, though certain differences are manifest. The frangulin-like body is not identical, and the percentage of *emodin* is much smaller. There is a much larger amount of resin and this is divisible into three distinct bodies. It is not clear to which of these differences the more regular and less griping characters are due. Throughout the recent active discussion of the presence of emodin, or emodin-like substances (*anthraquinones*) as active constituents of some of our most important cathartics, there has been shown a disposition to over-rate the effect of such presence as determining similarity of action. It by no means follows that other constituents are to be ignored in the laxative effects, merely because the anthraquinones are thus active; besides which, we have to reckon with minor differences in the anthraquinones themselves. The distinctly bitter properties of cascara sagrada make it more effective in stimulating appetite and digestion. Like buckthorn, it is much more useful when given in small doses, for some time, to overcome habitual constipation, than when used as a cathartic. It has been at various times claimed as a useful agent in the treatment of rheumatism, syphilis and similar diseases, and it is so by virtue of its depurative and eliminative properties, but not in any way as a specific. The actual physiological action of cascara sagrada has never yet been worked out, but it is evident that it in some way profoundly modifies the secretory and excretory functions. The fluid extract alone is official. The dose as a cathartic, taken at night, is 2 to 4 c.c. (fl. ʒ ss. to i.). Those few who find their rest thus disturbed may take it in the morning, or may take a smaller dose. As an alterative or tonic laxative, the dose is 1 to 2 c.c. (♏xv. to xxx.), preferably before meals. Licorice, alkalies, and carminative oils tend to disguise the bad taste.

None of the extracted so-called active constituents of the drug are worthy to be compared to its preparations.

Henry H. Rusby.

CASCARILLA.—"The bark of *Croton Eleuteria* Bennett (fam. *Euphorbiaceæ*)" (U. S. P.). This species of Croton is a large, widely branched shrub of the Bahama Islands.

Cascarilla was imported into Europe about the middle of the seventeenth century, when it was considered a variety of cinchona. It has undoubtedly formerly been the produce of several species of *Croton*, but at present comes exclusively from the one above named. It is in quills or curved pieces, about one-twelfth of an inch (2 mm.) thick, having a somewhat fissured, easily detached, brown, corky layer, more or less gray from a covering of lichens, and the inner surface smooth. It breaks with a short fracture, having a resinous and radially striate appearance. When burned, it emits a strong, aromatic odor. Its taste is warm and very bitter.

The active principles of this bark are *cascarillin*, a white crystalline, bitter substance, scarcely soluble in water, to which it owes its tonic properties, and an *essential oil*, which latter it contains to the extent of something more than one per cent. It also contains some *resin* and a little tannin.

The composition just given indicates the use and value of cascarilla. It is a bright, rather pleasant, aromatic, bitter tonic, with no special qualities other than its taste, to distinguish it in medicinal value from other spicy bitters. It is used occasionally in pastils, and is said to be put into tobacco on account of its fragrance when burning. Alcohol extracts its virtues to the best advantage. Dose, as a tonic, 1 or 2 gm. There is no official preparation.

The section *Eleuteria*, of the enormous genus *Croton*, contains thirty or more plants, a number of which have barks possessing properties similar to those of cascarilla.

W. P. Bolles.

CASEATION. See *Necrosis.*

CASEIN OINTMENT.—A thick, white emulsion, miscible with water and proposed by Unna as a vehicle for the application of drugs to the skin. Its formula is: Casein, 14; potassium and sodium hydroxides (1 to 4), .48; glycerin, 7; vaselin 21; salicylic acid or borax, 1; water, 56. As it dries it leaves a thin coating upon the skin.

W. A. Bastedo.

CASEOIODIN.—A substance of the nature of thyreoiodin stated to have been used with good results in myxœdema. The œdema subsided, the hair and skin became soft, the intelligence clearer, and the phlegmatic condition gave place to one of average activity. It is prepared from periodo-casein, and is a white powder containing 8.7 per cent. of iodine. The dose is gr. ⅛ once or twice a day, increased rapidly up to gr. i. a day. In overdose it is capable of producing flushing, rapid, weak heart, and prostration.

W. A. Bastedo.

CASHEW (or *Caju*) **NUTS.** *Anacardium.* The ripened ovary, with contents, of *Anacardium occidentale* L. (fam. *Anacardiaceæ*), a large, widely sprawling shrub, or small tree, of tropical America, largely cultivated in all tropical countries for its fruit. The edible portion of this fruit consists of the fleshy enlarged pedicel, and is of the form and size of a medium pear, green or yellow with a red cheek. It is juicy to an extraordinary degree, and is consumed chiefly for its thirst-quenching properties. Unless thoroughly ripe, it is exceedingly astringent. When ripe, the juice is slightly sweetish and slightly acid. This fruit is also manufactured into a wine which is credited in Brazil with special properties as a hepatic stimulant. The ripened ovary, many times smaller than the fleshy portion, is partly hidden in the summit of the latter. It is kidney-shaped, about 3 cm. (1.25 in.) long, brownish-ash colored, and smooth externally. It contains a large, bland, oily, curved, edible embryo. The pericarp, which is 2 or 3 mm. (⅛ in.), thick, is of cavernous structure, and contains when dry a thick or solid, black, extractiform, resinous substance, of exceedingly irritant properties when applied to the skin. A bassorin-like gum exudes from the stem; an edible milky sap, which also is an indelible dye, flows from the trunk.

The resinous extract consists of *anacardic acid*, and a yellow or brown oily liquid, *cardol*. This is an intense and dangerous irritant, causing often severe inflammation of the skin and blisters, and even the fumes, when it is burned, are said to have the same properties. It was formerly used as an irritant, and is still so used to some extent in the West Indies. It has no medicinal value here, and is only to be known as a poison.

The East Indian *anacardium* is a smaller but similar product, from *Semecarpus anacardium* Linn. *fil.*, in the same order. A milder cardol, "*Cardol pruriens*," is obtained from its fruit, and has been used also as an irritant, and as a basis of indelible ink. It is entirely out of use on account of the danger attending it. Poison ivy, *Rhus toxicodendron* L., and poison sumach, *Rhus venenatum*, are in the same family, and, as well as some other species of *Rhus*, have a similar inflaming action upon the skin (see *Poisonous Plants*).

W. P. Bolles.

CASSIA, PURGING; CASSIA FISTULA.—"The fruit of *Cassia Fistula* L. (fam. *Leguminosæ*)" (U. S. P). The British Pharmacopœia improves upon ours in its definition of this article, under the title *Cassiæ Pulpa*, as "The pulp obtained from the pods," this pulp being the only portion of the fruit used. The drug has been undoubtedly in use for five or six hundred years, but its name is much older, having been transferred to this substance from some variety of cinnamon to which it properly belonged. The tree is a native of tropical Asia, but is extensively cultivated for its beauty, both in the Old World and in the New. It is of medium size and produces long, drooping racemes of beautiful, showy, sweet-scented flowers.

The pods are nearly or quite straight, from 30 to 60 cm. long by about 2.25 cm. in diameter (12 to 24 in. by 1 in.), cylindrical, shortly stalked and blunt-pointed. The surface is dark purplish-brown, and although not very smooth it has a dull polish. The dorsal and ventral sutures are marked by broad, flat, longitudinally striated bands running the length of the pod. The position of the partitions is generally noticeable upon the surface by means of shallow, annular constrictions about 5 or 6 mm. (¼ to ⅕ in.) apart. The exocarp (shell) is hard and brittle when dry. The cavity is divided by transverse septa into from twenty-five to one hundred chambers, each containing one brown, shining, flattened seed and further filled with pulp. This last, when the pods are fresh, is soft and fills the entire space; as they dry it hardens into a thick, black, extract-like mass which eventually becomes hard and brittle and only covers the surfaces of the chambers, leaving the seed free and loose. When very dry, the quality is considered to be impaired. This pulp is removed for use by maceration. It has a sweetish, mawkish, mulberry-like taste and smell and is slightly laxative, but, at least in the dry state in which the fruits reach us, it has very little value. *Sugar, gum,* and other common vegetable substances are all that have been observed in it. Cassia Fistula is retained in the Pharmacopœia as a traditional ingredient of the Confection of Senna. In the south of Europe it is more used. Dose: of the pulp, from 4 to 12 gm. (ʒ i to iij.) as a laxative;

as a cathartic, two or three times as much. The official confection contains 10 per cent. each of senna and tamarind, 7 per cent. of prune, 12 per cent. of fig, 16 per cent. of cassia fistula, and one-half per cent. of oil of coriander, the rest sugar. The dose is 4 to 8 gm. (ʒ i to ij.). It is little used. *Henry H. Rusby.*

CASSIA.—Cassia Bark, Cassia Cinnamon, and Cassia Buds. See *Cinnamon.*

CASTALIAN MINERAL SPRINGS.—Inyo County, California. These springs are found near Owens Lake, and are thirteen in number, most of them being cold. One or two are sulphurous, and the others are alkaline and carbonated. The place is being developed as a resort. Some of the waters are also used commercially, and are recommended in cutaneous disease. The following analysis of one of the springs was made by Prof. Thomas Price, in 1880:

One United States Gallon Contains:

Solids.	Grains.
Sodium carbonate	1,724.11
Sodium sulphate	651.02
Sodium sulphate (?)	46.34
Sodium chloride	1,840.72
Potassium chloride	132.30
Lime	Trace.
Magnesia	Trace.
Silica	14.28
Boric acid	Trace.
Phosphoric acid	Trace.
Iodine	Trace.
Bromine	Trace.
Iron	Trace.
Organic matter	13.48
Total solids	4,422.25

Gases not determined.

This is an exceedingly dense alkaline-saline water and cannot be used medicinally without dilution. There are other springs close by which are not so heavily impregnated. *James K. Crook.*

CASTALIAN SPRINGS. Holmes County, Mississippi. Post-Office, Durant. Hotel. These springs are located three miles west of Durant, at the point of intersection of the Canton, Aberdeen and Nashville and the main line of the Illinois Central Railroad, and about 250 miles north of the Gulf Coast. There are from ten to twelve passenger trains arriving at and leaving Durant daily, all of which are met by the Castalian Springs stage line.

The country around the springs is generally rolling, with some high hills and beautiful valleys, making a charming combination. The location of the springs is about 300 feet above the sea level. Notwithstanding the great rainfall in this section, there is very little gloomy or cloudy weather. The clouds roll up quickly, discharge their contents and disperse, leaving Old Sol to resume his sway. The temperature about the springs ranges, on an average, from 35° F. in winter to 65° F. in summer. The greatest extremes ever noticed are 10° F. the lowest, to 90° F. the highest. The place is used as a resort both summer and winter. At present there are excellent accommodations for about 250 persons, but the resort is soon to be improved by the addition of a first-class new hotel with a capacity for 500 guests. The springs are situated in a pleasant little valley shaded by magnificent water-oaks, and surrounded by high hills with gradual slopes to the valley below. The hills are clad with evergreens of pine and some cedar. On the springs property which embraces some 360 acres, there are about fifty springs and wells, only two of which, however, have been analyzed or used for medicinal purposes. We have been able to secure these analyses, one of which is only a qualitative determination of the mineral ingredients, while the second is a quantitative one.

Spring No. 1.

(Examination by Prof. E. W. Hilgard, former State Geologist.)

One United States gallon contains 138.5 grains of solid matter, made up of the following ingredients in the order of their quantities:

Calcium sulphate.
Aluminum sulphate.
Magnesium sulphate.
Iron sulphate.
Iron carbonate.
Potassium sulphate.
Sodium chloride.
Silica.

Sulphureted hydrogen gas, strongly charged.
Carbonic acid gas, considerable quantities.

Professor Hilgard states that the waters may be classed as sulphureted-chalybeate. They possess the astringent qualities of alum water, while at the same time they have laxative properties from the presence of the sulphate of magnesium.

This spring yields about 600 gallons of water per hour, having a temperature of 56° F.

Spring No. 2.

(Prof. L. G. Patterson, present State Chemist, Analyst.)

One United States Gallon Contains:

Solids.	Grains.
Calcium sulphate	37.23
Magnesium sulphate	15.18
Sodium sulphate	8.68
Silica	7.35
Ferric and aluminum oxide	4.84
Sodium chloride	2.47
Potassium sulphate	1.29
Total	77.04

This spring flows about 300 gallons per hour. The water is used for bathing purposes, and is also sold by the barrel or case. It has long held a wide reputation in Mississippi for the treatment of the malarial cachexia and for liver, stomach, bowel, and skin affections. *James K. Crook.*

CASTOR.—*Castoreum.* The dried preputial follicles with their contents, obtained from the Beaver, *Castor Fiber* Linn., and separated from the somewhat shorter and smaller oil sacs, which are frequently attached to them. The glands or reservoirs are usually connected in pairs by their excretory ducts, which open so near together as to be removed without dividing. They are oblong or pear-shaped, somewhat shrivelled, multilocular bags, of dark-brown color (when dry) and tenacious consistence. The castor itself is within these; it is an unctuous brown or reddish-brown substance of intense and disagreeable smell. It consists of volatile *oil, castorin,* a *resinoid substance,* a peculiar fat, and other proximate principles, but like musk and others of its class the chemical composition is not especially instructive as to its qualities. There are two varieties of Castor, the Siberian, from the Siberian beaver, whose "pods" are longer (6 to 12 cm. = 2½ to 5 in.) and larger, and whose contents are more fragrant; and the Canadian, from the American variety. The latter is naturally the most common here.

This substance has been long used as a stimulant and antispasmodic in hysterical and other nervous conditions, but is now nearly obsolete as a medicine. It is no longer official either in this country or in Great Britain. There is some call for it as a basis of perfumes. Dose from .5 to 2 gm. (gr. viij to xxx.). *W. P. Bolles.*

CASTOR OIL.—Oleum Ricini. "A fixed oil expressed from the seeds of *Ricinus communis* L. (fam. *Euphorbiaceæ*)" (U. S. P.). In temperate climates, this plant is an annual, often dying at the season's close without ripening its fruit; or, where the season is long enough, as in the Middle States, it bears abundantly the first year, and is killed by the approach of winter; but below the frost line, as in the extreme south of Europe, in

Africa, and India, it becomes a shrubby or tree-like perennial, sometimes attaining, in the tropics, a height of forty feet. In the United States it usually attains a height of from three to twelve feet, with a round, very smooth, purple and glaucous, hollow, branching stem, and large, peltate or subpeltate, five- to eleven-lobed leaves. The flowers are borne in large, falsely axillary, paniculately branched spikes. The fruit is a short, blunt, prickly tricoccus capsule, containing three pendulous seeds. Castor-oil seeds vary considerably in size and markings; they are generally from 1 to 2 cm. (about ½ in.) in length by about two-thirds as broad and half as thick, ovoid, blunt, and rounded at the ends. They are convex on the outer surface. The inner surface is usually flattened on each side of the middle by the pressure of the neighboring carpels, the two facets so formed uniting in a very blunt and rounded longitudinal angle. They have a good-sized caruncle at their upper end (or a scar if this has been broken off). The surface is very smooth and shining, usually of a gray color, marked with very pretty brown or blackish marblings. In color and markings, however, they may vary considerably. The nucleus consists of a soft, oily albumen, with a good-sized, straight, broad embryo in the middle. This plant is probably indigenous to India, but has been cultivated so long and extensively that its original habitat is difficult to determine. It has been completely naturalized, and grows with all the freedom of a native in other parts of Asia, as well as in many of the Mediterranean islands and coasts. It is cultivated extensively for its seeds in India, Southern Europe, and the Middle United States. It is a very variable species, and is divided into numerous varieties, mostly distinguished by the size, shape, and color of capsules or seeds.

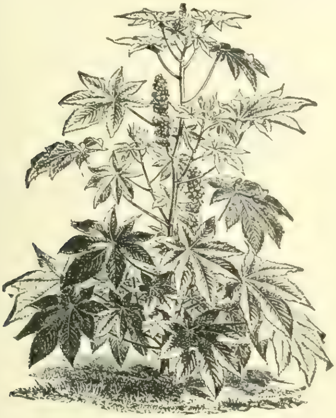

FIG. 1149.—Castor-oil Plant. (Baillon.)

The castor-oil plant was known to the ancient Egyptians and Greeks, and its oil was used for fuel, light, and medicine. It has even been suggested as the gourd that sheltered Jonah. After a long period of neglect, it was again brought into use, a hundred and twenty years ago, by Peter Canvane, a physician who had practised for many years in the West Indies, and who, in a treatise upon this oil, strongly recommended it as a gentle purgative (Pharmacographia).

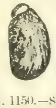

FIG. 1150.—Seed of the Above. Two-thirds natural size.

The oil is separated from the seeds by the usual methods employed with fatty substances, viz., by boiling in water and skimming it off; by extracting it by means of some solvent like alcohol or ether; or by expression. The latter is the method employed in the United States. The seeds are carefully cleared from dust and fragments of the capsules, and then warmed, by which means the oil becomes more liquid. The mass is then subjected to strong pressure, and the expressed oil further purified either by standing and decantation or by boiling with water. The yield is about forty or fifty per cent. The purer the oil is, the less active and griping it is. If expressed cold from the peeled seeds, like the best Italian oils, it is very white and odorless, and almost tasteless.

The higher the temperature employed in the process, the greater is the tendency toward the freeing of the irritating and griping *ricinoleic acid.* The pulp left after expression contains a small amount of the albuminoid *ricin,* which is a powerful irritant and convulsive poison. This substance renders the action of the seeds so violent as to unfit them for use as a medicine, though the practice prevails in some countries of triturating one or two with a dose of the oil, to render the latter more effective.

DESCRIPTION.—The following is the official description: A pale yellowish or almost colorless, transparent, viscid liquid, having a faint, mild odor, and a bland, afterward slightly acrid, and generally offensive taste.

Specific gravity: .950 to .970 at 15° C. (59° F.).

Soluble in an equal volume of alcohol, and, in all proportions, in absolute alcohol, or in glacial acetic acid; also soluble, at 15° C. (59° F.), in three times its volume of a mixture of 19 volumes of alcohol and 1 volume of water (absence of more than about 5 per cent. of *most other fixed oils*).

With an equal volume of benzin, it forms, at 15° C. (59° F.), a turbid mixture, but at 17° C. (62.6° F.) it yields a clear solution.

When exposed to the air in a thin layer, it slowly dries to a varnish-like film.

When cooled to 0° C. (32° F.) it becomes turbid, with the separation of crystalline flakes, and at about −18° C. (−0.4° F.) it congeals to a yellowish mass.

If 3 c.c. of the oil be shaken for a few minutes with 3 c.c. of carbon disulphide and 1 c.c. of sulphuric acid, the mixture should not acquire a blackish-brown color (absence of *many foreign oils*).

Castor oil consists almost wholly of a compound of *ricinoleic acid* ($C_{17}H_{32}[OH]COOH$) which is irritant and purgative when set free by saponification in the intestine.

Castor oil is a cathartic of very reliable character, more uniform and painless in its action, and more susceptible of gradation, than almost any other. The full dose clears the bowels with great certainty, producing numerous and copious discharges of their contents, with but little irritation of their surfaces; indeed, when these are inflamed it appears to have a decidedly healing or soothing effect upon them. On these accounts, when the desire is simply to relieve the entire intestinal tract, either from the accumulated fæces or from the irritating secretions of dysentery or enteritis, castor oil is the safest and surest means at the command of the physician. For attacks, also, of acute indigestion, and for the constipation following childbirth, it has long been almost universally used. It is not a hydragogue, nor is it very well adapted for continuous use in habitual constipation, although for "weak" and sensitive conditions of the bowels, when they are easily disturbed, now a little constipated, now a little loose, with frequent slight colics and flatulent tenderness, small daily doses of this medicine may be useful. Daily doses of ♏xx. to xl., before breakfast, are recommended by high authority for overcoming chronic constipation. It is one of the ingredients of flexible collodion (*Collodium flexile,* U. S. P.), to which it gives softness and flexibility.

ADMINISTRATION.—There is scarcely a medicine in use which is generally taken with so much repugnance as this. When it can be taken clear this is the best way, or it may be mixed with syrup or glycerin, or floated upon the surface of some aromatic water, or in the froth of soda-water containing some aromatic syrup; or a regular emulsion may be made with it, such as is made with cod-liver oil, by means of mucilage or other emulsifying agent. But the taste of the oil usually outlives that of the flavor, and these agents are, therefore, only partly successful. Another good way is to rinse the mouth with clear whiskey or other spirit, or lemon juice, then immediately to swallow the oil, and follow it with another rinsing with the liquor. If thoroughly emulsified, with the addition of orange juice, a confection is formed which is almost unobjectionable. Finally, it is put in elastic capsules, which for small doses, in the case of patients who will learn to swallow them, completely cover the taste. All these means, however, are more adapted to grown persons than children; for these the emulsion is probably the best, or it may be covered with a little lemon juice or glycerin. Another useful way to give castor oil, in certain cases, is by injection; in this way it acts principally locally and mechanically as a lubricant, but a certain quantity must be absorbed, as there is often more result from it than would be explained in this way. A good method is to give, for an adult, from 60 to 120 gm. (℥ ij. to iv.) clear, to leave it for from one-quarter to three-quarters of an hour in the bowel, and then to follow with a full enema of soap and water. Very free emptying of the lower bowel usually follows.

Castor oil is absorbed to a slight extent by the skin, but the method has no practical value.

Dose by the mouth, as a laxative, from 5 to 10 gm. (ʒ i. to iij.); as a purgative, from 15 to 30 gm. Children require large proportionate doses. A baby a week old can easily bear from 3 to 5 gm., and a child of five or six years, 10 or 15 gm. *Henry H. Rusby.*

CASTRATION.—The removal of the testicles or ovaries.

I. Historical Sketch of Castration in Men.

Castration is a very ancient practice. It was a consequence of the system of polygamy. The word eunuch means literally having charge of the bed-chamber. The Hebrew word means mutilated, and the first royal chamberlains were probably castrated men. Later the term eunuch was applied to men in all sorts of offices and it lost its original meaning. In some of the Eastern courts the eunuchs often played an important rôle and became so prominent in affairs of state that the word eunuch came practically to be the name of a great state officer, the chamberlain.

Eunuchs are represented on the bas-reliefs found during the excavations at Nineveh. "Here and there along the sculptured procession, in strong contrast to the bearded men, the eunuchs stand out with their smooth, beardless faces, fat cheeks and bald double chins. The artists adopted these features as a conventional mode of representing them."[*]

Herodotus relates that the castration of slaves was an industry among the Greeks. These slaves brought a high price in the markets of Ephesus. They were regarded as the most faithful and most capable servants. In Rome also there were numerous eunuchs. Castration has been a feature in certain religious doctrines, one at least of which taught that it was necessary for salvation. The beautiful soprano voices possessed by some of the eunuchs made them a prominent feature in the musical portions of religious services. We are indebted to Korsakow,[†] physician to the Russian Embassy, for interesting data concerning the eunuchs in China. Early records of castration in China date back to 1100 B.C. Next to beheading it was at one time the most severe form of punishment. The eunuchs are used as slaves in the royal household at the present time. Some are forcibly castrated, others submit voluntarily as a result of poverty, and others are sold into slavery as children by their parents.

In China the operation is usually performed in childhood. The trade is hereditary in certain families. The fee is about ten dollars. If the victim has no money the amputated genitalia are retained by the operator as surety. The operation is performed in the following manner. The genitalia are first completely anæsthetized. The specialists are said to possess a secret method of local anæsthesia. The external genitalia are then removed with one stroke of the knife. Crude methods of stopping the hemorrhage are employed. They have no notion of surgical asepsis. Dissection is forbidden by law and as a result they have no surgery. Retention and fatal sepsis are a common sequence. Incontinence may follow retention. In this case it is said that the approach of the patient may be recognized at a considerable distance on account of the strong odor of ammonia. Later the aperture of the urethra tends to contract and a wooden dilator is introduced and at first is worn constantly except during micturition. Even with these precautions retention follows in most cases as a result of cicatrization. With this are associated cystitis and the formation of vesical calculi.

The classical type is seldom seen in Pekin. The middle-aged eunuch differs little from other Chinamen. Those castrated in youth attain full stature. The timbre of the voice is like that of a woman. Those castrated after the age of twenty rapidly lose their hair and their voices become harsh and unpleasant. They age rapidly and at forty they give the impression of a person of sixty.

Lortet[*] says that in most of the large cities of Egypt one meets in the streets many eunuchs, attached to rich families as trusted servants, especially as servants and guards in the harems. The methods of operating among the Egyptians are barbarous and the mortality is great.

Many of the eunuchs castrated early in life were said to preserve the pure, clear timbre and high pitch of the boy's voice, adding to this the power of the grown man's lungs. In the Italian opera many of them attained prominence as really great singers.

"Reputable authors assert that," in Australia, "the wild natives limit the increase of families by crushing the testicles of the father after his first child is born."[*]

II. Effects of Castration on Male Animals.

Domestic animals are ordinarily castrated because they grow and fatten more quickly and are more valuable for working purposes. The effects of castration on animals are summarized by Andrews.[†] He gives an interesting account of the effect upon the elk as observed in two cases by the late Judge Caton, of Ottawa, Ill. "The course of horn growth in the uncastrated buck is this. Their so-called horns are not composed of real horny material but of true bone, and are developed into antlers of immense size. They are shed annually, as in all the deer tribe. During the spring and summer they grow rapidly. They are then covered with skin, hair, and connective tissue, and are supplied with numerous large arteries and veins running between the bone and the skin. This is the stage called 'the velvet.' Toward autumn a narrow, knobby ridge or ring of bone, like a narrow provisional callus, begins to develop around the base of each horn; the ridge pushes out and presses hard against the nutrient vessels supplying the horn, and in some weeks obliterates them. The velvety skin and connective tissue covering the antlers are cut off from nutrition and die. The bony horn itself also dies later and the dead skin dries and becomes loose, and the animal rubs it off among the trees and bushes, leaving the superb antlers in their perfected condition. The antlers now have no nutrition except a little derived from the small interior vessels of the cancellated tissue, which are soon obliterated. They are now two immense necrosed bones and in the course of the winter undergo a separation, like any other necrosed bone, and drop off. In the spring a new pair sprouts and develops, like their predecessors. Judge Caton found that if while the young horns were in the velvet the buck be castrated, the pair of horns then developing would go on, finish their growth, and be shed the following winter as usual; but the next pair were never shed. The effect of the castration is to prevent the formation of the bony ring at the base. Consequently the blood-vessels are not obliterated, the horns continue in the velvet, they do not die, and are not shed. In our climate, however, the severity of the winter freezes the antlers and kills them down to a point, perhaps, eight inches from the skull. The frozen parts ultimately drop off and in the spring numerous small horns, like fingers, sprout up from the stumps. The next winter these are partly frozen, and so on until a pair of large knobby bunches of bone stand up on top of the head.

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[*] Andrews, "The Oriental Eunuchs." Journal of the American Medical Association, xxx., 173-177, 1898.

[†] Korsakow, "Eunuchen in Pekin" (abstract). Deutsch. med. Wochenschr., xxiv., 338-340, 1898.

[*] Lortet, "Allongement des membres inférieurs du à la castration." Arch. d'Anthrop. Crim., xi., 361-364, 1896.

[†] Andrews, *Op. cit.*

"So far as I know, no one has tried protecting these horns from the winter's cold to see what they would grow to. They would probably attain an immense size."

The ox is larger than the bull but relatively the neck and forequarters are thinner. The cerebellum is said to be larger. The horns are greater in length and diameter. In the adult bull the voice in lowing is an octave higher than that of the ox. This is in contrast to the effect of castration upon the human voice.

The wool of the wether is said to contain less lanolin than that of the ram. This is of importance commercially. Castrated cats are excellent mousers. They are considerably larger than normal cats.

It is stated that among certain species of squirrels, the males, in fighting, castrate each other. There seems to be no doubt that many of those captured by hunters have been castrated in some way; but exactly how it occurs does not seem to be settled. The capon or castrated chicken is fifty per cent. heavier than the cock. The flesh is more delicate and more tender. "Their spurs remain undeveloped, the colored comb and wattles about the head remain very small, and the gay ornamental plumage of the cock is mostly wanting."

III. Effects of Castration on the Human Male

Castration in early life exerts profound developmental influences. The secondary sexual characters of the male are expressed in part by his greater size and strength and deeper, rougher voice. The origin of these characteristics is probably due to nervous or chemical influences originating in the testicles. Experimentally the invigorating effects of the injection of testicular extracts have been shown. Zoth[*] showed that daily injection for one week increased by fifty per cent. the working power of a man's neuro-muscular system. At the same time there were less susceptibility to fatigue and greater power of recovery. These nervous or chemical influences are not essential to health as in the case of the thyroid.

At puberty there occur acceleration of growth, changes in proportion, and the growth of the beard. The pitch of the voice may fall permanently an octave and for the time being may become rough, broken, and uncontrollable. This is due to a general sudden enlargement of the laryngeal cartilages, and a lengthening of the vocal cords. In the eunuch the size, shape, and consistency of the larynx correspond more to the condition in the boy than to that in the female. Calcification of the cartilages in old age does not occur. The timbre of the voice is boyish and the pitch is soprano.

Apparently no accurate observations have been made concerning the changes produced by castration in early youth. The results of the operation as performed in some of the Oriental countries can hardly be considered cases of uncomplicated castration. The forms of operation differ widely. In many cases the entire external genitalia are removed. Complications arising from sepsis and other conditions must also be considered. No general statement concerning the changes in general appearance and nourishment can be made. There is probably a general tendency to adipositas, in late life at least.

Statements as to the condition of the musculature vary. Hair does not develop on the chest, in the axillæ or on the pudenda, and no beard grows on the face.

The thyroid in Gruber's[*] case was very small.

The internal genital organs are small and undeveloped. This is the case with the penis also.

In animals an arrest of development in certain parts of the brain has been described. Statements concerning peculiarities of character and the mental capacity of Oriental eunuchs have been made, but they differ so widely that no general conclusions may be drawn. Some are described as weak and of a jealous, intriguing character. Others are said to possess great energy and ability. It is probable that the moral atmosphere in which they lived has considerable influence in determining these characteristics.

Effect on the Sexual Life.—Sturgis,[†] after giving an historical review, calls attention to the forensic importance of this subject. He concludes that in animals, for a varying period after complete castration, normal spermatozoa are found in the contents of the seminal vesicles. This period varies in different animals, being six days for the dog, seven for the cat, and fourteen days for the guinea-pig. In man clinical cases are recorded in which fecundation of the female has occurred after coitus with the male who has been completely castrated. The difficulty of controlling all the circumstances, however, is obvious. Still pursuing the analogy in man as in the dog and cat, a complete castrate may be capable of procreation provided the coitus occur within the first seven days after the castration.

The impossibility of drawing general conclusions from a small number of cases brings up the question of accessory testes. Apparently a few indubitable cases have been recorded in which the accessory testis has been removed and examined microscopically. Turner[‡] reports a case in which two testicles were found on the right side during an operation for hydrocele. One was situated above the other, the cords of the two apparently uniting. He also quotes a similar case reported by Lane. "Microscopical examination of the supernumerary testis showed well-formed tubules with spermatogenesis proceding." In neither of these cases, however, does there seem to have been a microscopical examination of what was considered to be the normal testis. It seems quite possible that in some cases of apparently complete castration normal functionating testes may be situated even intra-abdominally.

This is important also in connection with the question of the effect of castration on the sexual passion. It is said that sexual desire may persist after castration in manhood and may develop occasionally even when the operation has been performed in childhood. The ox and the gelding do not completely lose the sexual passion.

Castration for Enlarged Prostate.—The physiological relations existing between the testes and the prostate, the faulty development of the prostate after castration in early years, and the conception of an analogy existing between the hypertrophied prostate and myomata of the uterus, led to the performance of castration as a therapeutic measure in cases of prostatic hypertrophy.

From a developmental point of view the analogy between the hypertrophied prostate and uterine myomata is not well founded. Only the sinus pocularis, a remnant of the Müllerian duct, corresponds to the uterus. Anatomically and histologically the similarity to uterine myomata of the so-called myomatous form of hypertrophy is only superficial.

The faulty development and small size of the prostate after castration in childhood and the retrogressive changes following the operation in early manhood, indicate only the effects upon a normal organ. Here, however, we are dealing with an hypertrophic and pathologically altered gland.

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[*] Zoth. Quoted by Lee, "Reproduction," in "American Text-book of Physiology," 878, 1896.

[*] Gruber quoted by Becker, "Ueber das Knochensystem eines Castraten." Arch. f. Anat. u. Entwickelungsgesch., 83 112, Leipsic, 1899.

[†] Sturgis, "Are Complete Castrates Capable of Procreation?" Med. News, lxxiii., 449, 1898.

[‡] Turner, "A Case of Supernumerary Testis." The Lancet, ii., 174, 1900.

Following castration in animals there is an atrophy of the glandular portions of the prostate. In most cases of hypertrophy there is an increase in the volume of the fibro-muscular stroma. The pure glandular forms are relatively uncommon. An atrophy of the glandular portions alone would have little influence in reducing the size of the organ.

Retarded development of the prostate in congenital malformation and malposition (cryptorchismus) of the testes has been described. Apparently there have been a few cases of hypertrophy after castration in youth.

The danger of the operation in old patients has led to modifications of various kinds. Among these may be mentioned unilateral castration, division of the cord, ligation of the cord, division or resection of the vasa deferentia, division of Cooper's nerves, angio-neurectomy, and sclerogenous injection. These do not appear to be as effective as the original operation.

Many good results of the operation have been reported by trustworthy observers. Many very experienced surgeons report only bad results.

Although the sexual operations for prostatic hypertrophy have often been performed, and there is no lack of experimental evidence of the effect of castration on the normal gland, yet one cannot say that the relations of this operation have as yet been entirely cleared up. The indications have not yet been adequately determined, and one cannot say in any case what the result will be. The method in which castration brings about the result is still rather obscure, and the changes which the hypertrophied prostate undergoes have been little observed at autopsy or studied histologically. The observations have yielded no noteworthy results. In almost all cases an atrophy could not be demonstrated.

Important considerations are the effect on the central nervous system and the general effects. In old patients there is often rapid exhaustion of strength. Cases of acute mania have been reported. These effects may be due to the loss of an internal secretion. Frisch[*] has given up the sexual operations entirely. Three of his patients who were cheerful and strong before operation and had no evidence of involvement of the kidneys or other internal organs died within fourteen days after resection, as a result of a loss of strength amounting almost to cachexia.

The greater part of the publications on the subject are incomplete. A cure involves a condition in which the patient spontaneously completely empties the bladder within the normal interval. This fact is often lost sight of. Reports of a decrease in the size of the prostate are seldom based on accurate measurements. Œdema caused by retention is probably relieved, but the same result is attained by catheterization. Some of the reported cases have been operated on during the first period of retention.

There are a few apparently reliable cases in which the results were very satisfactory. Spontaneous micturition developed gradually and later a decrease in the size of the prostate could be demonstrated and was permanent. There was a decrease of residual urine and a disappearance of the obstruction and the cystitis. The contractility of the bladder returned after years of catheterization or the patients were more readily catheterized. The soft forms of hypertrophy are most influenced. Fatal results are frequently due to secondary changes in the kidneys.

The results of nursing, rest, and treatment of the cystitis are apt to complicate the observations, and cases given simply symptomatic treatment often yield equally good results.

It has not been decided what relation enlargement of the prostate bears to difficult micturition. There may be symptoms without much enlargement, and many old men with large prostates have no symptoms. The severity of the symptoms does not depend entirely upon the degree of hypertrophy. The hypertrophy is not physiological, but is caused by proliferation of a typical tissue and the result is much like that due to the presence of a neoplasm. There is possibly an embryological *Anlage*[*] for the condition.

Most of the reported brilliant results have followed within a few days after the operation. They have possibly been a result of depletion of the venous networks, with which the prostate and the neck and walls of the bladder are supplied. These vessels communicate freely. Their congestion probably has a great influence on causing the symptoms. A distended bladder probably causes passive congestion in these vessels. In a short time this results in swelling and œdema of the neck of the bladder and of the prostate, and consequent closure of the orifice of the bladder. Castration possibly relieves this congestion by vaso-motor or other influences.

The late publications of some of the best observers indicate that the operation is at present employed only to a slight extent. Mikulicz[†] would limit the indications for the operation markedly. Frisch's[‡] opinion, as expressed at the Thirteenth International Medical Congress, is as follows: "Of all the various operations for hypertrophy of the prostate only those which have for their object the complete removal of that portion of the prostate which prevents the free flow of urine offer any chance of lasting success." Under this head he does not include any of the operations involving the testicles.

The conclusions of Lequeu[§] are reported as follows, from the same meeting: "As regards the remote results of double castration they are not so good as the early observations, which did not take a long enough space of time into consideration, would lead one to believe. The prostate certainly shrunk, but the patient improved to a far greater degree than could be accounted for by the diminution observed. The attacks of pain were less frequent and the contractility of the bladder improved so that the residual urine was less in quantity. But, after all, there was only amelioration and not permanent cure, and comparing the results of castration with those of other methods it was doubtful whether the advantages of it were worth the sacrifice."

The mental state of the patient, resulting from the change in his relations to society, must also be considered.

Effects of Castration on the Osseous System.—Becker[‖] has made some very interesting observations upon the effects of castration on the osseous system. His material consisted of the skeleton of a colored eunuch and the pelvic bones of another. These he compared with the skeletons of two colored males upon whom the operation had not been performed.

The general structure of the skeleton is slender as in the young negro. Ossification is delayed. This is true of the skull, the vertebræ, and the extremities, with the shoulder and pelvic girdles. The sutures and epiphyseal lines are very clearly retained and present the condition found in very young individuals. In Gruber's[¶] case the normal ossification of the hyoid bone was absent. The bones in general are very long, making the skeleton very tall. The same thing is observed in the ox and the gelding, both of which have long extremities and high withers. The relations of the lower to the upper extremities are analogous to those found in the young individual. The same is true of the relations of the forearm to the arm and of the legs to the thigh. In the pelvis no characteristic changes are found.

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[*] Frisch, "Die Krankheiten der Prostata," in Nothnagel's "Specielle Path. u. Therapie," xix., 1899.

[*] The German word *Anlage* is variously rendered rudiment, origin, beginning, basis, foundation, fundament.

[†] Hoffman, "Beiträge zur operativen Behandlung der Prostatahypertrophie." Beiträge zur klinischen Chirurgie, xix., 541, 1897.

[‡] Frisch, "The Remote Effects of Operative Treatment in Hypertrophy of the Prostate." Thirteenth Internat. Med. Congress, August, 1900. Reported by Phil. Med. Journ., vi., 325, 1900.

[§] Lequeu, *Ibid.*, 326.

Becker, "Ueber das Knochensysten eines Castraten." Arch. f. Anat. u. Entwickelungsgesch. 83-112, 1899.

[¶] Gruber, quoted by Becker, *Ibid.*

These results confirm those of Lortet.[*] He performed an autopsy on an Egyptian eunuch about twenty-five years old. The length of the long bones was considerably increased. This was especially marked in the lower extremities. It has been shown experimentally that the hind legs of the castrated rabbit are abnormally long. In the capon the foot is elongated. It is especially the hind legs of the ox that are elongated. As a result the line of the back is horizontal instead of descending as in the bull.

Effect of Castration on Sociological Conditions.—Castration has been employed in some countries as a method for the punishment of crime. Asexualization for the limitation of disease and the prevention and punishment of crime has been urged to some extent at the present time. It has been maintained that the castration of chronic criminals, sexual perverts, and hereditary defectives would benefit society and elevate the human race. It has been proposed as a substitute for capital punishment and as a means of preventing the propagation of criminals. "The pleading of Brower,[†] that asexualization is the most promising means of reducing crime, has been put on a practical basis by the suggestion of McCassey that criminals, especially those imprisoned for rape, should be offered their liberty at any time on condition of submitting to castration previous to discharge."

The editor of the Philadelphia *Medical Journal*[‡] apparently favors legislation along this line, as may be judged from the following:

"As we ascend in the social scale, with the present state of society, especially in the large cities, the number constituting a family becomes smaller and smaller. It requires no mathematician to discover that the shiftless, the thriftless, the indigent poor—the class which produces, relatively, the greatest number of criminals and paupers, if not of the mentally deficient—are increasing out of all proportion to the thrifty, the well-to-do, the class which produces relatively few of the paupers and criminals."

Two causes for this may be assigned. The growing dislike on the part of parents of the upper and middle classes to be burdened with numerous children and the lavish free treatment by hospitals, dispensaries, and lying-in institutions to all who apply. "Never was such organized or persistent effort put forth to save the weakling, the physically incompetent, those who with less care would perish in the battle for life.

"This effort at saving life is well, it is our duty; but it has its evil consequences. Parents relieved from much that is onerous in child-rearing are encouraged to beget others of their kind. Thus is beginning a multiplication of the indigent population which threatens serious consequences for the future.

"If the confirmed criminal, the pauper, the degenerate, those who have ceased to have a regard for law and the consequences of their own acts, must be supported by the state, then society certainly has the right to say that such at least shall not propagate their kind. It is stated that Michigan has legalized asexualization for certain of these unfortunates. Other States and countries will in time follow her example.

"Asexualization will be held by some to be a harsh measure, but it becomes incumbent upon those who would discourage it to offer something better, for the future will compel us to act. Regulation of the marriage law would be ineffectual, because these lower classes have ceased to have respect for the law and the consequences of their own acts.

"If society by her philanthropic efforts is forced to annul the law of the survival of the fittest, then self-interest, nay self-preservation, will compel her to adopt measures that will prevent the multiplication of those who at best can only add degeneracy to the race."

IV. Effects of Castration in Women.

Advances in gynecological pathology have made castration a much less common operation than it has been in the past. Many conditions formerly considered pathological are now recognized as normal. Regeneration and restoration of function follow more conservative operations in large classes of cases in which radical procedures were formerly considered necessary.

It is difficult to get accurate data concerning many of the remote effects of castration "because women are naturally reticent about matters of sex." Many of the patients are ignorant and unable to give intelligent accounts of their condition.

The classification of the effects of castration here adopted is that of Pfister.[*] Many of the ingenious applications of Pflüger's theory also are his.

Influence on Menstruation.—Before considering the effects of castration upon menstruation a brief consideration of some of the theories of menstruation is necessary. According to Pflüger's theory menstruation is the result of ovulation. The ovarian nerve endings are stimulated by the enlargement of the Graafian follicles in the ovary. The nerve supply of the ovary is very abundant, and the presence of ganglion cells has been described. The ovarian nerves have their centre in the lumbar region of the spinal cord. In this centre a summation of these stimuli takes place. The enlargement and bursting of the Graafian follicles is a continuous process. When the summation has reached a certain degree the stimuli are reflected to the vaso-motor apparatus of the uterus and ovaries. Meanwhile changes have been going on in the uterus. There has been formed the decidua menstrualis. This consists of a loose, succulent, and very vascular tissue. When the stimuli are reflected to the vaso-motor apparatus of the uterus a state of marked hyperæmia is brought about. Under the influence of this hyperæmia the capillaries burst and the menstrual flow is established.

The stimulus caused by the enlargement of the follicles has been replaced experimentally by artificial means. The injection of sterile gelatin into the ovaries of bitches is said to have caused an immediate onset of the symptoms of rut.

In addition to its function of ovulation the ovary probably furnishes also an internal secretion, to which the cause of menstruation has been attributed. Of the existence of this secretion, however, there is no absolute demonstration, such as, for instance, the internal secretion of glycogen in the case of the liver. The assumption that it possesses this function rests upon the striking anatomical and physiological homologies existing between the ovary and the internal secretive glands, and upon the disastrous results which follow its removal during the period of its functional activity. It may be that the function ceases also at the menopause, and that many of the associated symptoms are due to its discontinuance.

More tangible evidence of the internal secretive function of the ovary is furnished by the experiments of Curatulo.[†] After castration he found the phosphates (P_2O_5) in the urine greatly and permanently reduced in quantity. These results have been confirmed in man.

The beneficial effects of castration in cases of osteomalacia appear to be explained by these experiments. By the removal of the ovaries the excretion of the phosphates, which so largely constitute the inorganic, rigid portions of bone, is diminished. In this disease, however, no constant gross or histological changes in the ovaries have been described.

To what is to be attributed the periodicity of menstruation? Pflüger's theory offers an answer to this question also. If a ripe follicle chances to be present when the reflex hyperæmia of the ovary occurs, its bursting is hastened. This explains the cases in which ovulation is coincident with menstruation. If no ripe follicle is present, however, ovulation does not occur. In lower animals the rutting season and ovulation are synchronous. The periodicity of menstruation, then, is independent of ovulation. Pflüger's theory assigns the cause to the periodic formation of the decidua menstrualis. The reflex hyperæmia does not cause menstruation unless the decidua menstrualis has been completely formed.

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[*] Lortet, "Allongement des membres inférieurs du à la castration." Arch. d'Anthrop. Crim., xi., 361–364, 1896.

[†] Johnston, Am. Year-Book of Med., 519, 1900.

[‡] "Crime, Pauperism, and Mental Deficiency." Phil. Med. Journ., vi., 427, 1900.

[*] Pfister, "Die Wirkung der Castration auf den weiblichen Organismus." Archiv f. Gynäkologie, lvi., 853, 1898.

[†] Curatulo, "Influence of Removal of Ovaries on Metabolism in Connection with Osteomalacia." Obst. Trans., London, xxxix., 58, 1897.

If Pflüger's theory or the theory of internal secretion is correct, menstruation should cease after castration. Cases are repeatedly found in the literature in which it is said to have continued after the operation. In such cases it is probable that a portion of the ovarian tissue has escaped the operator and remained in place. In some cases this may have been in the form of accessory ovaries. These have been found at autopsy in such a relation that they might readily escape removal at operation. It seems that only a small amount of ovarian tissue is sufficient to continue the functions of the ovaries. A case has been reported in which a multilocular cyst developed after panhysterectomy. Pfister,* Clark,† and Kelly ‡ believe that complete castration always results in absolute and permanent cessation of the catamenial flow.

Following the operation of castration, it has been observed in some cases that the succeeding menstrual period has occurred, but has begun earlier than usual. According to Pflüger's theory, there should have been no succeeding period. Pfister regards it as a result of the severe mechanical stimulation of the ovarian nerves that necessarily takes place during the operation. This takes the place of the stimulation normally produced by the enlargement of the Graafian follicles.

The normal periodical flow has continued for a time after castration in some cases, and has then ceased at an earlier stage of life than normally. Here the operation has undoubtedly been incomplete. The early cessation is to be explained by the exhaustion of the remaining ovarian tissue. The number of Graafian follicles is limited and the supply gives out at an earlier period than normally.

Still another anomaly may be explained by Pflüger's theory. Menstruation may cease for a time after castration, and then may be re-established. In these cases the remaining ovarian tissue contains possibly only very young follicles. It is conceivable that these develop only very slowly at first. Later, when they become more mature, their growth is sufficiently rapid to bring about the necessary stimulation of the ovarian nerve endings.

It is significant that most cases in which menstruation persists after castration present technical difficulties at operation. These are often of such a character as to render it practically impossible to remove all of the ovarian tissue. They often take the form of dense adhesions to surrounding structures. Pfister reports two cases of unicornate uterus. Menstruation persisted after unilateral castrations. He believes that the "*Anlage*" and development of the ovary were bilateral, and that the anatomical relations of one organ were so atypical that it could not be discovered at operation, and consequently remained to continue its functions.

Following castration there are sometimes so-called vicarious hemorrhages. In a series of 116 cases Pfister noted their presence in 12. Two of these, in which periodical bleeding from the intestine occurred, he regards as genuine. In the other 10 cases the patients complained of periodical nose-bleed continuing for from one to two years.

The effects of the operation upon leucorrhœa are usually beneficial, and the condition improves or disappears. The change is not noted at first, but develops gradually with the retrogressive changes in the genitalia. In cases in which myomata are present the diminution is not so marked as in other cases. This is probably to be explained by the presence of submucous myomata, which possibly mechanically continue the process which leads to the exudation. In the case of submucous myomata there are usually increased blood supply and hypertrophy of the endometrium. Castration results in a decreased blood supply and atrophy of the mucosa. The improvement after the operation suggests that leucorrhœa is a result of this increased blood supply and hypertrophy.

Molimina Menstrualia.—This term designates the unpleasant sensations which often take the place of menstruation after castration. The etiology is possibly associated with a continuance of the periodical formation of the decidua menstrualis. The absence of stimulation from the ovary, however, prevents menstruation. With the gradual atrophy of the uterus the decidua menstrualis is no longer formed, and the symptoms disappear. Clark * believes that the decidua menstrualis is not formed at all after castration. According to the theory of internal secretion the symptoms are to be explained by a discontinuance of this function. The view that auto-intoxication is responsible for the molimina has also been advanced. Hippocrates believed that menstruation was a cleansing process for the purpose of ridding the system of impurities. The Hebrews † considered their women to be unclean during and for seven days following menstruation, and imposed severe penalties in cases of sexual congress during this period.

The sensations are local and general. They are variously described by the patients. There are sensations of heat, chilly sensations, dizziness, meteorism, pain in the back, pain in the abdomen, drawing pains, especially at the sides of the uterus, pain in the abdomen which not infrequently radiates to neighboring parts, sensations as of blood rushing toward the pelvic organs associated with feelings of fulness, weight, and dragging. Pfister noted their presence in thirty per cent. of the cases of his series. They were most pronounced shortly after the operation, persisting in some cases as long as two years.

Effect on the Sexual Life.—The normal physiological phenomena of the sexual life may be expressed in terms of Pflüger's theory. The tension of the Graafian follicles stimulates the endings of the ovarian nerves. This brings about a state of increased irritability of centres in the lumbar region of the spinal cord. Under these circumstances the patient is very susceptible to sexual stimuli. Cutaneous and other stimuli may now arouse the sexual passion. At other times much greater stimuli may be necessary to bring about the result. In coitus the erotic sensations are produced by the mechanical irritation of the glans clitoridis. The glans contains a rich network of nerve fibres. These end in peculiar structures known as Krause's tactile corpuscles. The mechanical stimulation probably brings about the erotic sensations in the lumbar region of the spinal cord. The irritability of these centres is probably increased by the stimuli from the ovaries passing through the ovarian nerves. This increased irritability is expressed by an increase in the intensity of the erotic sensations.

According to Pflüger's theory, then, castration results in complete extinction of the sexual passion leading to sexual impulses, and of erotic sensations during coitus. Pfister found that in forty-three per cent. of his cases the sexual passion no longer existed, and that in fifty-two per cent. there was a cessation of the erotic sensations. He notes also that Gläveke and Liesau arrived at similar conclusions. In the case of young individuals, he finds that the theory always holds good. He also quotes Beimler as having a similar experience. He offers an interesting explanation of the discrepancy. In the older individuals the sexual function has been active for a greater or lesser period of time. This has led to the development of a new factor. There have been formed in the central nervous system memory pictures of previous experiences—the libido centralis. These serve to awaken and maintain the sexual passion independently of the libido sexualis, which has for its basis the centres in the lumbar cord. The sexual life loses then the character of a purely physiological function. It comes to be partially dependent upon psychical influences. In support of this view he quotes Beimler's experiments upon dogs. Some of the dogs were castrated after one or more pregnancies, and others were castrated before any pregnancy had occurred. The former showed symptoms of heat after the operation, while the latter had no such symptoms. He offers a similar explanation from Keppler's case also. This was the case of a prostitute upon whom the operation of castration had been performed. She afterward continued her vocation. When her chosen lover was indifferent to her she submitted herself to him passively. When he was capable of arousing her interest, however, the sexual passion was aroused. Clark* reports the case of a variety actress who had suffered from gonorrhœa for a number of years. The sexual passion had been almost abolished by constant suffering. Double pyosalpinx and severe pelvic peritonitis finally necessitated a double salpingo-oöphorectomy. Two or three years after operation, with renewed health, the sexual passion had returned with almost double force. In the same way may be explained the persistence of the sexual passion in some normal individuals until after the sixth decade.

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* *Op. cit.*

† Clark, "Influence of Castration upon the Female Constitution." Progressive Medicine, ii., 141, 1899.

‡ Kelly, "Operative Gynecology," ii., 163, New York, 1898.

* *Op. cit.*

† Leviticus xv., 19.

Certain general considerations also have a bearing upon this point. In the male sex the degree of sexual inclination is fairly uniform. In the female, however, the degree varies greatly. "Concerning this point Prof. von Rosthorn, of Prague, made the startling statement to me, in a conversation upon this subject, that of all the women who consulted him at least seventy per cent., he felt convinced, had been indifferent to the sexual approaches of their husbands or lovers, even while they were yet in perfect health. In view of such statements it at once becomes evident that the post-operative side of this question cannot be determined definitely without control records of the sexual proclivities of the patients before they became ill."† As a rule the sexual passion decreases with the approach of the climacterium. In many cases the post-operative state may be a result, not so much of the operation, as of the approaching menopause. In other cases it is possible that an inflammatory process may vicariously take the function of the ovary in stimulating the ovarian nerves. The sexual impulses and the erotic sensations are usually affected to an equal extent.

The Effect upon the Genital Organs.—In the normal climacterium there is an increase of the connective tissue in the ovary, associated with the disappearance of the follicles. The other genital organs, especially the uterus, become atrophied. A similar result follows castration. The epithelium of the endometrium loses its cilia and becomes cubical, and the interglandular tissue becomes atrophic and cirrhotic. If myomata are present they take part in the general atrophy. The atrophy of the vagina, of the clitoris, and of the labia majora is less constant, but in some cases corresponds to that of the climacterium. This relation of the vagina and the external genitalia is especially interesting when considered in connection with the effect of castration upon the sexual passion and the erotic sensation. The origin and persistence of sexual inclination and the trophic relations of the vagina and external genitalia are not so dependent upon the function of the ovary as are the uterus and menstruation. Cases in which this general atrophy does not occur must be regarded as instances of incomplete castration. Occasionally, as a result of atrophic changes in the vagina, sexual intercourse becomes very painful, or even impossible. Clark ‡ reports such a condition in a woman who was previously neurotic. The dyspareunia resulted in abandonment of the woman by her husband. In young animals the uterus does not develop after castration. This is probably a result of the absence of reflex hyperæmia from the ovaries.

There is a tendency of the breasts to take part in the general atrophy. Mistakes may arise, however, as a result of a general increase of subcutaneous fat.

General Effects.—At the time of the natural menopause the female organization undergoes considerable changes. There is an alteration of the general form of the body. This is, to a certain extent, a result of the general increase of the adipose tissue. The changes in the face are conspicuous. The cheeks and the lower part of the chin become broader and more massive. There is an increase in the general contour of the body. The trunk and especially the hips and gluteal regions become thicker and wider. It is largely the distribution of the subcutaneous adipose tissue which lends to the youthful female form its peculiar charm. After the menopause the condition is changed. The connective tissue which separates and supports the fat lobules becomes loose. As a result the skin and subcutaneous tissue hang more loosely. The hair tends to lose its pigment. Chloasmata frequently develop in the skin of the face and scattered bristle-like hairs often make their appearance. There is a general increase of fat in the breasts, in the abdominal region, and in the extremities. Many of these changes contribute toward bringing about the characteristic matronly appearance.

After castration one might expect similar changes. A decided tendency toward greater deposition of fat is present. In a few cases this reaches an extraordinary degree. It must be remembered however, that the general health of most of the patients before operation is very poor. Convalescence, then, may be, to a certain extent, responsible for the result in some cases. The distribution of fat, however, is somewhat different. Except in the case of the patients who are at the age when the organism is preparing itself for the natural climax, the matronly appearance does not develop. The distribution of the fat is more like that of the youthful form. The patients appear brighter and more youthful. The complexion is clearer, the pigmentation of the skin is less marked and more uniform. The hair does not often turn gray early, pre-existing chloasmata often disappear.

The breasts are not dependent. The nipple is often atrophic, and its areola frequently loses its brownish pigmentation and becomes pink. The growth of hair upon the face does not take place.

As in the natural climacterium these changes require a number of years for their accomplishment.

Effect on the Nervous System and the Psychical Effects.—The effects of castration upon the nervous system vary greatly in character. Flushes in various parts are among the most common symptoms. Often, however, they have been present before operation, suggesting a tendency toward hysteria. They are described as sensations of heat passing from the pelvis toward the heart and lungs, even to the head. With these may be associated palpitation, dizziness, and tinnitus aurium. The skin becomes hyperæmic and even while the face, for example, is flushed and feels hot, the patients complain of sudden chilly sensations, especially in the back, passing up along the spine. Sweating occasionally occurs. The flushes are most marked shortly after operation, commonly with exacerbations corresponding to the menstrual periods. Varying much in intensity in the different cases, they usually sooner or later disappear.

Headache is often complained of. Where it has existed before operation, the patients frequently assert that the intensity is increased.

Occasionally nausea, vomiting, neuralgia, especially in the lumbar plexus, palpitation, sleeplessness, convulsive coughing, or chronic hoarseness supervene.

The nervous symptoms are more pronounced than in the normal menopause. This is probably a result of the sudden and complete removal of the ovarian tissue, in place of its gradual exhaustion by normal processes. Often the patients have been in poor health, possibly for years, before operation, and no doubt the long-continued suffering has effected a permanent injury to the nervous system.

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* *Op. cit.* † *Op. cit.* ‡ *Op. cit.*

Especially in the consideration of the psychical effects the previous state must be taken into account. Often the suffering has been so intense and long continued, and the general environment has been so depressing, that the patients are eager to submit themselves to a dangerous operation that offers any prospect of relief. The immediate rise in spirits may be simply a result of convalescence. As a rule the improvement develops only gradually as in the natural menopause, which is often introduced and accompanied by mental depression.

A weakening of the memory is frequently complained of. This may be simply a momentary forgetfulness of immediate occupation or an increase in the difficulty of recalling past events and experiences.

Severe nervous disturbances may result from the removal of the ovaries even in the forties.

Insanity does not follow castration any more frequently than it does other surgical operations.

Therapeutic Results.—In most cases the results are good, and in a few cases even ideal. The large majority of the patients lead an endurable life after years of suffering. Most of them are able to work after being in a state of partial or complete disability. As a rule they are satisfied with the results of the operation and often express their gratitude for their restoration.

The results of course differ with the indications for operation. The least complicated results follow in cases in which castration has been performed for inoperable myomata. Almost without exception atrophy of these tumors takes place and they may even entirely disappear. Myomata are poorly vascularized and their disappearance is no doubt due to the decreased blood supply. The results are equally beneficial in cases of ovarian or mechanical dysmenorrhœa caused by displacements of the uterus and atrophy of the vagina.

Hysteria appears to be practically unaffected, even when the organic disease is relieved. The same is true of hystero-epilepsy.

The death rate from the uncomplicated operation is practically nil. The pathological conditions which necessitate castration are so frequently complicated, however, that the mortality is raised somewhat. The death rate then becomes that of the complication.

Kelly,* in making a plea for conservatism in gynecological operations, speaks of the effect of unilateral ovariotomy. He presents an analysis by Dr. J. H. Durkee, of 228 cases of unilateral castration, in women under 40 years of age, and draws the following conclusions: "The comparison of the advantage and disadvantage of leaving in an apparently sound ovary is—in each case the average chance of having one child as contrasted with the risks of a recurrence of the disease in 2.6 per cent. of the cases. If the mortality of ovariotomy is 5 per cent. then the risk of death is thirteen to one against it even if the disease recur."

"Ovulation and pregnancy under suitable conditions, are, to a degree unappreciable to the male mind, essential elements of woman's happiness. To dwell upon this point would be but to reiterate what any attentive surgeon may gather from his daily experience in the consulting-room, and to rehearse well-known facts in the history of womankind.

"C. Schroeder stated that one of his reasons for the preservation of part of an ovary was to preserve the function of ovulation, *even if it were accompanied by but a theoretical possibility of conception.*"

After unilateral castration pregnancy may occur if only the tube of the opposite side is present.

As in the case of other bilaterally symmetrical organs, the removal of one ovary results, in the rabbit at least, in a compensatory hypertrophy of the opposite organ.

Interesting experiments in ovarian transplantation have been reported by a number of investigators. Normal pregnancies are said to have followed the operation performed on castrated animals. It has not been shown whether all of the functions of the ovary are performed under these abnormal conditions. Schultz * performed transplantation experiments upon guinea-pigs. Corpora lutea were formed in the ovaries under the new conditions. He showed that the female organization is not necessary for the growth of the ovary, but that ovaries transplanted to the male animal will adapt themselves to their new habitat. He found no evidence of the formation of corpora lutea, however.

Many reports of the beneficial results of organotherapy after castration have appeared in the literature, but no such brilliant results as in the case of athyria have been obtained. Favorable influences upon almost all of the unpleasant symptoms have been claimed, but reports vary considerably. Ovarian and thyroid extracts have been used.

The beneficial effects of castration in cases of osteomalacia have been referred to above.

The question has also a sociological aspect. "My own continued experience only serves to confirm my opinion that the castration of women is often a direct cause of domestic unhappiness and that it has been repeatedly used by men as a good reason for breaking off engagements, and for the violation of marriage vows, and the abandonment of wife and children."† Many of the effects upon society in general are readily conceived.

H. S. Steensland.

CATALEPSY.—The cataleptic state, or one analogous to it, has been observed in a number of living beings in ascending the scale of evolution from the *Drochocephale Virginiana* to man. Owing to the protean forms assumed by catalepsy, and the presence of frequent complications, not to mention the strange theories advanced by ancient authors, and the comments thereon, it is difficult to define the malady with clearness and precision. But among the more important writers of the present age, whose tendency is to substitute the scientific interpretation of morbid phenomena for the sciolistic rendering of apocryphal knowledge, the cataleptic condition is understood to mean a remittent neurosis of the cerebro-spinal system, unaccompanied by fever, and characterized by attacks of variable duration, during which there is almost always suspension or perversion of consciousness and of sensibility, and always interruption of voluntary motion, with general or partial tension of the muscular system, and aptitude of animal life to receive and to keep different degrees of contraction impressed by extrinsic force or assistance.

General Characters.—Much of the present obscurity concerning this curious neuro-muscular trouble is owing to the theories of a mythical pathology when the study of hysteria was but little advanced or the diagnosis of the neuroses was vague and only depended upon the stigmata described by the school of Salpêtrière. Some regard catalepsy as a malady, others as a symptom, while still others deny its existence outside of alienation. Since the time of Galen, who appears to have been the first to recognize its coexistence with mental troubles (Comm. ii., in Hipp. Præd. edit. Kuhn, t. xvi., pp. 682–684), three successive theories relative thereto may be noted: 1. A neurosis that may complicate certain mental maladies. 2. A simple symptom that may supervene in all mental diseases. 3. One of the principal motor troubles of tension characteristic of a special disease, as katatonia or stuporous melancholia.

Idiopathic catalepsy, as wonderful as it is rare, is an apyretic brain malady manifested by remittent attacks separated by intervals of health. Its special physiognomy is owing to the waxy position and plasticity of the limbs, and it is the only neurosis in which muscular contractions are possessed with abolition of the will. Either sex may be attacked, and the disease may occur in childhood or occasionally in advanced age, a case being noted in a man of seventy-five years; but women are more subject than men, and it occurs mostly about puberty or between the twentieth and thirtieth years, generally in persons of dull minds and sluggish physical organization. Cataleptic paroxysms may be spoken of as atypical. The fantastic characters of the cataleptic state render all clinical description absolutely obscure; so that the actual observance of a single case, or the study of a series of well-reported histories, will do more to throw light on the question than all the symptomatic enumerations that form the basis of these descriptions.

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* *Op. cit.*

* Schultz, Centralblatt f. allgem. Path. u. path. Anat., xi., 200, 1900.
† Kelly, *Op. cit.*

SYMPTOMS.—Systematic observance of cataleptic symptoms relates chiefly to the three orders of pathological phenomena of the mind, sensation, and motion. An attack coming on in a nervous or melancholic individual may be sudden and all the functions of the life of relation appear entirely abolished. There is complete suspension of mental action, with cutaneous anæsthesia, loss of thermic sensibility, and rigidity and inertness of the limbs, which retain the position given to them. This rigidity is described by the old Latin authors in such picturesque locutions as *stipitis* or *trunci instar*, and *mortui ritu jacens*. In some cases the attack may have such precursory symptoms as headache, insomnia, vertigo, hiccough, epigastric pain, a feeling of constriction in the throat, trembling of individual muscles, an undefined sense of discomfort, and different hysteriform nervous troubles. When suddenly attacked the patient remains motionless in the attitude had at the moment when struck. Patients have become cataleptic while drinking tea, playing cards, ascending a ladder, during attitudes of devotion, and the like, and have retained the position held at the time of attack. The various positions a cataleptic may be made to assume have been compared to those of a manikin, to a statue with springs or with limbs of soft wax, which preserve any constrained position or inflexion given to them for a comparatively long period. The muscles of the breast and the inspiratory muscles are unaffected during a cataleptic seizure; and it is probable that the digestive functions go on regularly, although the phenomena of absorption and nutrition operate with extreme slowness. The secretions and excretions are lessened, and even suspended, cataleptics having been known to go for twenty-five days without a voluntary evacuation and to undergo long abstinences, leaving them in the condition of hibernating animals. Consciousness, though mostly abolished, is not so in all cases, the suspension of sensorial function being more apparent than real. With the general disturbance of the vital processes there is almost entire abolition of the functions of special sense. The mucous membrane of the nose, however, retains its sensitiveness slightly, and the act of swallowing may be performed when the substance to be ingested is placed deeply in the pharynx. Reflex irritability is sometimes lost, but the electric contractility of the muscles remains. Respiration is slow and tranquil; the pulse normal in rhythm, though sluggish and at times almost imperceptible. The pupils are dilated, and the fundus of the eye shows paleness of the choroids, with straight and attenuated retinal vessels. The temperature being lowered two to four degrees below the normal, the patient becomes icy cold, deadly pale, and expressionless—a condition that may easily be mistaken for death. In fact the annals of medicine record illustrative cases of apparent death from this cause, in which the victim has narrowly escaped burial alive. The old schoolman, Duns Scotus, is an instance of a resuscitated cataleptic. A case often quoted is that of a woman who was placed in a family vault, presumably dead, and having regained consciousness during the night, and fortunately finding the vault unlocked, returned home to her husband, and after this strange episode lived to bear a large family of sons and daughters. The event is commemorated by a monument and an inscription in the Lutheran cathedral at Magdeburg; and it is suggested that the possibility of such occurrences may account for the custom that obtains in some parts of Germany of placing a bell above the public receptacles for the dead, and fastening the hand of the ostensible corpse to the rope, that it may be rung in the event of consciousness being regained. An instance is related in France of a cataleptic who was on two occasions the chance victim of hastily rendered funeral honors. Now and then one reads in newspapers of women being taken away for burial while in a cataleptic trance, and only recovering consciousness when being lowered into the grave. A woman in a trance having been buried alive in Naples, the court sentenced both the doctor who signed the certificate and the mayor who authorized the interment to three months' imprisonment for "involuntary manslaughter." Such mistakes could hardly happen nowadays, provided ordinary precautionary measures are taken to discriminate real from apparent death, such as the auscultatory signs, the indications furnished by the thermometer, the electric contractility of the muscles, and the ligature of a finger or a toe.

The attack over, the patient suddenly regains consciousness, sometimes after epistaxis or the appearance of the menses, and there is usually no recollection of what has happened during the attack. Headache and general lassitude generally follow for a short time. The attack may disappear and be transferred into another neurosis or into a vesania. There is great variability in the number and duration of the attacks, which may last for minutes or hours, or entire months. The malady has been known to disappear after one attack; while in another patient as many as seven hundred paroxysms have been counted. The attacks may, moreover, be very irregular in manner, or they may be periodic, and even occur during sleep. There is no mental disorder in the intervals of simple catalepsy; but when the catalepsy is a symptom of profound nervous disease it may be associated with ecstasy and somnambulism, or the occurrence of hysterical convulsions, delirium, maniacal attacks, and hallucinations. For this reason it is generally held that cataleptics are responsible for their acts during intervals, except when there is a complication.

The condition represented by the picture outlined in the foregoing remarks is often modified or softened down into the incomplete form, which, though not having all the symptoms of what may be called ideal catalepsy, exhibits nevertheless, in a different degree, the motor and sensory disorders, and electrical reactions characteristic of the disease in question.

COMPLICATIONS.—Catalepsy may be associated with another nervous affection, such as hysteria, ecstasy, somnambulism, tetanus, mania, hypochondria, and lypemania; or with a disorder of an entirely different nature, as pneumonia, typhoid fever, meningitis, rheumatism, intermittent fever, etc. It is complicated and mixed in *hystero-catalepsy*. Without doubt hysteria developed independently of mental alienation is the neurosis with which catalepsy affects the most frequent relations and narrowest affinities. As one and the same morbid state they proceed from a common origin, and doubtless are closely related. Muscular rigidity in this form varies as to the degree, not being in positive relation with cutaneous anæsthesia, but almost always proportional to the depth of lethargy and to the volume of the muscles concerned in the movements of the articulations. Persistence of muscular tension, with absence of sensibility and fatigue, are spoken of in connection with this state as a new variety of perturbation of voluntary motility. Systematic writers describe hystero-catalepsy as general or partial, complete or incomplete, and transitory or permanent. In rare cases it is unilateral.

Ecstatic catalepsy has been often observed in ecstatic women and in priests. The records of sorcery and demonography abound in instances, historic and modern, of women becoming cataleptic during certain religious observances, of priests who become so at certain stages of the mass, and of monks who throw themselves into prolonged cataleptic ecstasies. No less a writer than Balzac speaks of profound meditation and fine ecstasy as catalepsy in the bud. Doubtless many of the queer sects mentioned by Dr. Hepworth Dixon, in "New America," are made up of individuals whose mental condition is more or less influenced by this disordered state. Anthropologically and pathologically speaking, the same remark would apply to various so-called religious ceremonies that have obtained among all races in the times of all the prophets, from Moses to the Latter-Day Saints of Salt Lake City, and in the worship of all the gods from Jupiter to the latest theosophic misconception; and however much we may respect the courage implied in the expression of a sincere opinion, it is impossible not to detect the further existence of this disordered state as shown in numerous sciolistic writings, notably those of Dale Owen, Swedenborg, and the theosophists. Moreover, it needs but little observation to trace the prevalence of the same morbid influence among clairvoyants, spiritualists, and even the ardent admirers of Madame Blavatsky.

Catalepsy with somnambulism is a complication in which the phenomena of catalepsy and the symptom of somnambulism are bound one to the other, and succeed in a regular order in such a manner as to form a single attack. They are sometimes distinct, independent of each other, and separated often by long intervals.

The disease may occur with other accessories, as catalepsy with tetanus, catalepsy with epilepsy, and with chorea, the chorea happening in the daytime and the catalepsy at night during sleep. Catalepsy may also exist with permanent contraction of the feet and hands; with delirium and melancholy, with acute and chronic mania, and with dementia and idiotism. It is a frequent complication of paranoia, and is sometimes, though rarely, associated with hypochondria. We may occasionally see in the subject hysteria, catalepsy, ecstasy, and somnambulism succeed, turn by turn, and mix one with the other, with a frequency entirely out of the regular order of things and an intensity unheard of. This extraordinary mixture of cerebral neuroses was met with in its highest degree in the great convulsive epidemics of the Middle Ages, during the sixteenth, seventeenth, and eighteenth centuries; and their occurrence having become a matter of history and common hackneyed observation with writers on kindred subjects, it suffices to give them merely a passing mention. Catalepsy is met with in acute dementia, stupidity, and other non-determined cerebral affections. The cataleptic states may still be manifested in the greater part of the neuroses, and in diverse affections of the brain, and with such acute diseases as pneumonia, typhoid fever, acute articular rheumatism, intermittent fever, and worms. Verminous catalepsy has been noted and commented upon by various writers.

Epidemic catalepsy, like many of the neuroses, may become contagious by imitation under mesological circumstances favorable to its propagation. Such circumstances exist when the disease occurs in an assemblage of impressionable subjects, as a school or a convent, a camp-meeting, or a spiritualistic gathering, where a twofold predisposition is to be found in the nervous temperament and in certain questionable hygienic and moral conditions. In former epidemics, the disease seen in its most startling and complete expression exhibited a terrible spectacle and mixture of all the neuroses and all the vesanias. It was common for celibate and ascetic persons to show the strangest nervous symptoms; to fall cataleptic at mass or during other religious observances, and to exhibit the complex symptoms of hysteria, demonopathy, and catalepsy.

Catalepsy and cataleptoid phenomena may be provoked artificially in hysterical or other predisposed, impressionable and nervous persons, through mental suggestion, or by intense light, the sonorous vibrations of a tuning-fork, and by pressure on the ovaries. These artificially induced conditions have been studied by various persons, who think the condition should properly be called *syggignostic*.

Pathological Anatomy.—The physiological cause of this and of allied conditions is presumed to be inhibitory arrest of activity of certain tracts of the ganglion cells of the brain cortex. It is, however, impossible to say in the present state of scientific observation whether inhibitory lesions exist or not in catalepsy; but it is probable that there is, in addition to muscular inhibition, a morbid element, the essential nature of which is unknown. Such superficial alterations as considerable development of the Pacchionian bodies and injection of the meninges found after death from catalepsy are insufficient to explain the symptoms during life; and the inflammatory exudation or alterations found in the central organs, with softening of the optic thalamus and corpus striatum, are lesions rather to be associated with other diseases than with catalepsy, since they were present as complications in the observed cases; therefore, until something more complete is known of the morbid anatomy of catalepsy, it must be regarded as a violent excitement, a sort of tension, a cerebral cramp, the result of a purely dynamic lesion of the cerebro-spinal nerve centres whose function is to preside at the determination and co-ordination of movement.

Causation.—If the pathological nature of catalepsy is obscure and unknown, its causes are extremely numerous, and present a particular interest. Nervous exhaustion is the most common predisponent, and of all the etiological moments hysteria is the most prominent. Catalepsy and insanity usually march together. Many authorities declare that no catalepsy can exist unless accompanied or followed by a psychosis. Acquired or innate predispositions are found in persons of great nervous susceptibility and unsteadiness, or in those of a nervous and melancholic temperament with a previous neurosis, and rendered more susceptible by chlorosis, masturbation, or progressive spinal paralysis. Tumors, tuberculous meningitis, and other chronic cerebral diseases, may also give rise to cataleptic manifestations. Atavistic influences seem to account for some cases of catalepsy. It does not appear that the disease is ever directly transmitted, although heredity as a general cause seems to preside over its development in many observed cases.

The causes that may provoke a cataleptic crisis are numerous and varied, and it often follows diverse circumstances, as excess of work, religious excitement, violent fright, deep chagrin, an attack of anger or indignation, gastro-intestinal irritation, sudden cessation of the menses, unrequited love, and worms. It may result in a transitory form from diffused encephalitis, or as one of the sequels of typhus or malarial fever, of acute articular rheumatism, uræmia, the puerperal state, auto-intoxication, and pneumonia. Partial catalepsy may also be in consequence of the narcotic inhalation of ether or chloroform, of poisoning by lead or carbon dioxide, hashish, or alcohol, and it may result from being struck by lightning. In fact, any toxic substance or any concomitant psychosis may put into activity the cataleptic state. The production of crises, by looking fixedly or for some time at a bright object, and vividly riveting the mind on the image is one of the proceedings of Braidism or Mesmerism. Among the hack observations of medical writers are those relating to the Franciscan friars, who became cataleptic at mass during the elevation of the host. It is known that the monks of Mount Athos go into a state of cataleptic ecstasy by looking fixedly at the umbilicus; Indian fakirs fall into catalepsy by looking a quarter of an hour at the end of their nose; Egyptian sorcerers procure sleep and insensibility by similar details; Arab sorcerers of Cairo, by looking steadfastly into the palm of the hand; and it is related of Cagliostro that he brought on somnambulic crises by similar means. Instances of psychic shock, like that of a woman who became cataleptic every time she saw a certain man who had insulted her, or that of an indignant French judge, who suddenly became cataleptic when insulted in court, incline one to the opinion that such expressions as "petrified with indignation," "motionless with surprise," and the like, though merely implied comparisons, are not always to be taken in the metaphorical sense.

Diagnosis.—The marks that constitute the essential and pathognomonic character of catalepsy, as complete or partial aptitude of the limbs to preserve during a relatively long time the position given to them, and the impossibility of the patient to modify this attitude, along with unconsciousness, anæsthesia, and analgesia, should make the matter of diagnosis easy. Embarrassment is most likely to occur in cases of simulation, or when it is a question of discriminating between hysteria, tetanus, ecstasy, coma, lethargy, syncope, congelation, and cadaveric rigidity. In the matter of simulation it is only necessary to test the sensibility, the reflex irritability, and the electrical contractility of the muscles, and to try the influence of mental suggestion. In cases associated with hysteria the distinction is a matter of no therapeutic importance. It may be well to question whether the condition is from a cerebral lesion or of toxic cause. The neuro-muscular system of animal life being alone affected during an attack, that of vegetative life is without loss, as is shown by the persistence of circulation and respiration, which distinguishes catalepsy from syncope or asphyxia. The general history of the case should cause no confusion in diagnosticating catalepsy from the affections with which it may be associated.

Prognosis.—Many regard catalepsy as the index of a predisposition carried to a high degree and by itself not dangerous to life, but a disease in which recoveries are rare. Some recent authorities think otherwise in regard to the prognosis, and Hammond pronounces it favorable even in severe cases, as all his patients recovered under treatment. In cases resulting from malarial infection the prognosis is better. The same may be said of acute attacks resulting from injury, from worms, or from mental shock in comparatively healthy persons. The retention of smell and taste is indicative of returning health. Cases complicated with hysteria or the psychoses are most grave. Death may be in consequence of anæmia or of inanition.

Treatment.—To arrest an attack of catalepsy efforts may be made to arouse the patient by peripheral irritation, as that caused by a pinch of snuff or the inhalation of a few drops of amyl nitrite. Quinine and morphine in combination are recommended in periodic cases of malarial origin, and vermicidal remedies are called for in catalepsy caused by intestinal parasites. Tonics, iron, ergot, and apomorphine hypodermically—gr. $\frac{1}{20}$—have all been recommended. The most efficacious medical treatment yet reported consists in the administration of one of the bromides in combination with zinc oxide, and the simultaneous use of strychnine and other tonics. Acupuncture, faradic electricity, hydro-therapeutics, and change of air are useful adjuncts to the treatment. In addition to meeting symptomatic indications, moral hygiene of the most rigid kind should be enforced, and it is of prime importance that all emotional or religious excitement be avoided. The mind should be disciplined; home influences are to be broken up; and every effort should be made to establish the general conditions of health, which must prevail before the morbid action can really be effaced. *Irving C. Rosse.*

CATALPA. See *Poisonous Plants.*

CATAPHORESIS.—If two fluids of different density are separated by a membrane, the fluids diffuse through such membrane until they are of equal density. This process has been called osmosis. If the two electrodes of a galvanic battery are placed in two compartments of a fluid separated from each other by a porous septum, the fluid particles pass in the direction from the positive pole to the negative pole, so that the fluid in the one vessel increases, while it decreases in the other. The amount of fluid thus conveyed in a unit of time is larger the stronger the current and the smaller the conducting power of the fluid. This phenomenon has received many names, among which electrical osmosis, electrical diffusion, and cataphoresis are the best known, but the last one bids fair to remain in general favor. Cataphoresis, as Billings tersely puts it, is the power of the galvanic current to induce osmosis from the positive to the negative pole.

Cataphoresis, which, scientifically speaking, means merely the action of the galvanic current, has in medical language acquired the meaning of introducing medical substances into the body through the unbroken skin, and is now almost exclusively used in this sense. If a definite quantity of medicine in solution is placed on a disc or sponge electrode at the positive pole of a battery, and applied to a certain spot of the body, while the negative pole is placed anywhere in contact with the body, a local anæsthesia is produced around the positive pole if the substance experimented with is cocaine, while the entrance of quinine, strychnine, and many other drugs into the body by this method can be demonstrated by their presence in the urine or the saliva. Mention of attempts made in this direction date back as far as 1747, but not until 1853 do we find scientific demonstrations of the fact. From that date until to-day the matter has been investigated by physicists, physiologists, and physicians, in both Europe and America. Electrodes have been invented suitable to the different purposes of administering the drugs, but while cataphoresis is beautifully simple in theory and to the physicist, its practical application to every-day medicine is almost exclusively confined to members of the dental profession, who use it most successfully to anæsthetize sensitive dentine and gums with cocaine, and for the bleaching of teeth.

In medical practice cataphoresis has found but scant favor. Neurologists have produced deep local anæsthesia with cocaine cataphoresis where before large doses of morphine were needed to produce the same effect. The substitution of the former drug for the latter has been advocated enthusiastically in cases in which a possible morphine habit loomed up threateningly; but whether a cocaine habit is preferable to a morphine habit is a subject open for discussion. The discovery of cocaine and the ease with which local anæsthesia can be produced by its hypodermic use have undoubtedly reduced the importance of further investigations of cataphoresis for such purposes, and to the busy general practitioner the subject remains more or less a medical curiosity.

How far the action of the cataphoric current in itself can induce or produce nutritive changes in the living cells is a question which opens an unlimited field for research. The so-called Porret's phenomenon shows that its action on living protoplasm closely resembles that on fluids outside of the body, for if applied to muscular fibres the current induces a streaming movement from the positive to the negative pole in the protoplasmic contents of the fibres, so that they swell at the negative and decrease in size at the positive pole; and if the electrodes are changed, the action is reversed. Only a very arbitrary opinion may be ventured in deciding whether such compulsory rearrangement of the protoplasm can be looked upon as beneficial or harmful, and until we have more definite knowledge of the subject, the application of the cataphoric current as a mere stimulus to any part of the human body, aside from its electrolytic action, must remain, from a scientific standpoint, mere guesswork. Whatever beneficial results are reported must be accepted as due to chance, or perhaps to the imagination of the patient. It is, however, safe to predict that when medicine becomes a science, and we know the specific medication necessary to stimulate or rebuild certain definite organs or parts of organs, cataphoresis will receive its due share of attention and assume its proper place. Attempts to force iodine into goitres and lithium salts into gouty joints are crude experiments in the right direction. While we know that such medicine can be forced into a definite part by cataphoresis, we must wait until further investigations demonstrate that the cells of that part will and do assimilate the medicines driven into their substance; for unless such assimilation and subsequent excretion do take place, which change the worn-out or diseased cells into healthy ones, the medical substances introduced will act as foreign bodies and produce irritation instead of improvement. *Julius Pohlman.*

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CATARACT is the morbid impairment of the transparency of the crystalline lens, or of its enclosing capsule, and is lenticular or capsular, according to its situation. A less important division is that into true and false cataract, the latter being caused by deposits on the capsule, the result of disease.

Cataract may be stationary or progressive, partial or total. It may be cortical or nuclear, according as it affects the cortical substance or the nucleus of the lens. When confined to the vicinity of either pole it is denominated anterior polar or posterior polar, in conformity with its position. The old division into hard and soft is rarely used at the present day, the consistence of the cataract largely depending on the age of the individual. Cataracts are moreover divided, according to the stage of development in which they are encountered, into incipient, mature, and hypermature. Finally, they may be classed as simple or complicated; as simple when dependent on or associated with no known disease, either local or general; as complicated when proceeding from an affection of the system at large, such as diabetes; or, from an impairment of the eye itself, like glaucoma or separation of the retina.

DIAGNOSIS.—*Objective Symptoms.*—The modern methods of investigation render the diagnosis of cataract a matter of certainty. By their aid the slightest opacity of the crystalline lens can be detected and correctly located, and they have wholly superseded the old "catoptric test," which depended on the reflected images from the anterior and posterior capsules, and the disappearance of the latter when an opaque substance intervened before it. Recourse is now had to the concentration of light on the eye by means of a convex lens, and to the illumination of its interior by means of the ophthalmoscopic mirror. In either case the pupil should ordinarily be dilated by the application of one of the usual mydriatics, duboisine, homatropine, or atropine. The first of these acts with the most rapidity, the second produces the most temporary effect, while the third is the one most generally accessible. Previous to using the mydriatic the tension of the eye should be carefully noted. Should it be found to be excessive, no attempt to dilate the pupil is admissible.

The pupil being dilated, and the rays of a lamp, placed 30 to 50 cm. from the patient's head, concentrated obliquely on the crystalline by means of a convex lens of short focus, 18 D. to 15 D. (2 to 2½ in. focal length), any capsular and many lenticular opacities are rendered plainly visible. A second lens, held before the observed eye, may be used to magnify their distinctness. But it is necessary to bear in mind that, with advancing years, the outlines of even a normal crystalline lens assume increased distinctness. Its anterior surface takes on a silky lustre, the fibrous structure becomes more and more visible, while age gives the nucleus additional density and a yellowish reflex that may often prove deceptive. No absolute diagnosis of cataract must be based on the appearance of a grayish cloudiness in the centre of the pupil until the ophthalmoscope has been brought to bear on the spot. In this method of examination the mirror is alone used, being held at about the reading distance of the observer from the patient's eye. The vivid red of the illuminated pupil remains unbroken when the media are clear, and the returning light traverses a transparent crystalline. When, however, this is not the case, the smallest opacities are distinctly seen as dots, shadows, or stripes against the bright background. Their precise situation is made out when the observer moves his own head to one side, opacities situated in the front of the lens moving in the same, those at its back in a reverse direction. The differential diagnosis between lenticular and other opacities of the transparent media is easily made, corneal spots being distinguished by oblique illumination, floating bodies in the vitreous by their mobility.

So great is the danger of mistaking the reflex from the pupil, due to advancing age, for cataract, when the examination is made by day and with the unassisted eye, that a diagnosis should rarely be made until both methods here described have been employed.

Subjective Symptoms.—When an individual who has passed middle life begins suddenly to grow near-sighted, to see distant objects better through a concave glass, and to lay aside his usual reading-glasses, or even to require a weak concave for this purpose, commencing cataract may be suspected, and this even when no opacity of the crystalline is as yet visible. This state of the refraction is by no means invariable, but happens with tolerable frequency, and explains some of the cases of "second sight," or the returning vision of the aged, a popular belief in which is so widely spread. Much more general is the occurrence of multiple vision with a single eye. The patient sees several new moons in the sky instead of one, and the flames of the street lamps are no longer clearly defined, but seem to shoot out long rays in all directions, or else several lights are seen in the place of one. The lens, in these cases, seems to undergo a separation into sectors, possessing different powers of refraction, prior to becoming the seat of actual cataract. As the disease advances the acuteness of vision falls off. At first near, and later distant, objects are distinguished with increasing difficulty. Points of light loom up as if seen through a fog. A characteristic symptom is the change produced in the appearance of objects by varying degrees of illumination. In the majority of cases the cataract patient sees best before sunrise, after sunset, when the sky is overcast, or on a dull day. He is confused and blinded by a sudden increase in the amount of light around him, such as would be caused by the sun emerging from behind a cloud. The use of a mydriatic renders him to some extent again independent, and atropine may thus often be employed with advantage to eke out and prolong vision that is being reduced from this cause, and where the opacity of the lens will be found to be mainly central. In the rarer cases, in which obscuration commences at the periphery, enlargement of the pupil exposes the imperfect portions of the crystalline and causes a disturbance of sight. Such patients see best through a contracted pupil, and instinctively crave an excess of light.

DIAGNOSIS OF MATURITY.—As the success of the operation for cataract is always greatest in cases in which the disease is fully formed, the question of ripeness becomes an important one, and may easily be settled. Oblique illumination should show the lens to be opaque up to its front. No layer of transparent substance is to intervene immediately behind the pupil. When the cataract is mature the iris is seen to be in direct contact with the opaque lens, and the edge of the pupil throws no shadow when the source of illumination is moved a little more to one side. In addition to all this, however, it is important to ascertain that each anterior chamber is of equal depth, that the iris of the eye affected with cataract is not bulged forward beyond the plane occupied by its fellow. For such bulging indicates the lens to be in what is called the "period of swelling." Just before the opacity of the cortical substance becomes entire, its fibres often appear to swell and separate, the lens grows apparently larger and presses forward, frequently restricting the motions of the pupil. In time this process recedes, the lens loses in volume, and its mass becomes more compact, thus offering a more favorable opportunity for the operation of extraction. The period of swelling should therefore ordinarily be allowed to subside.

FUNCTIONAL EXAMINATION.—It is hardly necessary to dwell on the fallacy of the popular notion that, in a case of cataract, blindness must occur before the operation becomes admissible. Many a patient, misled by this belief, has waited until the last perception of light had died away, and then presented himself to the surgeon for treatment, to be met with the announcement that the disease was not a cataract, and that treatment had only been possible while some vision remained. An opaque lens merely interposes a screen, more or less translucent, to the passage of light, an appreciable amount of which still filters through. Where no perception of light remains, therefore, no restoration of sight is possible. The patient must be able to make out not only the presence, but the position, of a luminous object. Having ascertained, by covering the other eye, that the one affected has a general perception of light, that the pupil expands and contracts in accordance with the degree of illumination, and that the position of a window can be pointed out, it is well to test more carefully the sensitiveness of both the central and the lateral portions of the retina. The patient is taken into a dark room, the good eye carefully covered, and the gaze of the other fixed in a given direction. This may be brought about by desiring the patient to hold up one of his own hands, at arm's length, on a level with his eye and straight before him, and directing him to look persistently toward the spot where he knows this hand to be. A lighted candle is first held as close as possible to the hand he is fixing, and then moved in the same plane up, down, and to either side successively; the patient being required to indicate each new position of the candle, without removing his eye from the direction of his own hand. If he sees the light each time its position is changed, it is certain that the whole extent of the retina retains its normal sensitiveness; if he fails to observe it in one direction, the powers of the retina are correspondingly impaired. When the light, on being moved upward, can no longer be located, the lower portion of the retina is destitute of perception, and it must be borne in mind that here is the usual position of a retinal separation. When he sees the light laterally, but not straight before him, the region of the macula lutea is generally diseased, and the power of reading is unlikely to be regained, even after a successful operation.

CAUSATION OF CATARACT.—Our knowledge on this point is extremely limited. Becker's[1] researches go to show that senile cataract originates in an interruption of the progressive sclerosis of the lens. Attacked with this disease it shows in the outset a decided contraction of volume. The cortical substance is thus, as it were, split up. The intervals thus left are at first filled with the normal fluid, the index of refraction of which subsequently changes, thus making the divisions more plainly visible by transmitted light. Actual opacity now begins to occur, the fluid constituents of the lens increase, and its volume augments. The microscope shows changes in the fluid, molecular opacity, and swelling in the fibres; the places of which latter in the cortical are subsequently occupied by the products of degeneration.[2]

But all this brings us no nearer the cause of cataract. It is broadly stated that it is due to an impaired nutrition of the lens. This merely gives the difficulty another name. How is this nutrition effected? The crystalline body possesses neither nerves nor vessels, is suspended between two fluids, the aqueous humor on one side and the vitreous on the other, each similarly devoid of vessels, and probably in some way receives its nourishment through them. That substances introduced into the general circulation may ultimately be detected in the lens has been shown by experiment, although a considerable interval must elapse before their arrival occurs. They are supplied to the aqueous and vitreous by the vessels of the surrounding parts, and through them to the lens itself. Impaired nutrition of these two humors may therefore indirectly be the cause of cataract.

It is certain, on the one hand, that there must be some predisposition in the system at large, as senile cataract almost invariably attacks both eyes, although at different periods. It is equally certain that there must exist some local, modifying factor, inasmuch as the most diseased eye is always first attacked. This statement is based on the well-known fact that the prognosis in the second eye is usually better than that in the first.

VARIETIES OF CATARACT. — *Congenital.*— These are either partial or total, more generally the former, occurring in the shape of sharply defined opacities. It may in general be said of cataracts of this class that they are the result of defective formation, and are accompanied by a certain amount of amblyopia or imperfect perception; which not only persists after the mechanical obstruction to the entrance of light is removed, but is apt to increase with advancing years, if the eye be left alone, thus rendering advisable the early performance of the operation. Very different in this respect is senile cataract, which may last without impairing the functions of the retina behind it.

1. *Zonular Cataract.*—This may be either congenital or met with in the earliest years of life, and is, according to Graefe, the most frequent of all the forms occurring in childhood. A central zone or shell of the crystalline is affected, circular in shape, surrounding and surrounded by entirely transparent lens substance. Seen from the front, by oblique light, or through the ophthalmoscopic mirror, it appears like an opaque or partially opaque nucleus to an otherwise transparent lens; and closer examination reveals its own centre to be transparent. Its diameter ordinarily varies between 5 and 8 mm. Sometimes this layer is surrounded externally by a second, equally opaque; sometimes, instead of a complete layer, groups of opaque points or striæ are irregularly distributed, with large intervals of clear lens periphery between them. In many cases the whole volume of the lens has suffered diminution. Zonular cataract is invariably met with in both eyes. It is frequently found that the children in whom it occurs have been the subjects of convulsions. They are, also, sometimes the victims of rachitis. This disease of the lens, when congenital, generally occupies a lesser area at birth than subsequently, and is hence often overlooked in very early life. Its subjects may be recognized by the way in which they shade their eyes to get the advantage of a dilated pupil, going into dark corners to thread a needle or perform some task requiring more than usual eyesight. In this connection it is desirable to refer to the proper treatment of zonular cataract. Its object being the admission of more light to the eye, two methods at once suggest themselves, the one being the formation of an artificial pupil opposite a clear space in the lens periphery, the other the removal of the lens itself, by discission in the young, by extraction in the case of one advanced in years. Each of these methods has its advantages and disadvantages. A successful iridectomy relieves the patient from the necessity of the life-long use of heavy lenses for all purposes, but is of no value if the cataract subsequently becomes total, as is sometimes the case. A full dilatation of the pupil is therefore to be brought about and the effect on vision noted. If much improvement follows iridectomy is indicated, particularly if the cataract has the appearance of being non-progressive and if the history of the case shows that vision has not materially changed for some time. But if vision does not improve under mydriasis, or if there is a history of diminishing vision, the lens should be removed.

2. *Punctated Cataract* consists in a large number of extremely small points of opacity, scattered throughout the lens. At the anterior and posterior poles they are often grouped into a triangular figure composed of short lines, meeting at an angle of 120°. The figure at the anterior pole has not the same direction as that at the posterior. Under strong illumination the opacity takes on a bluish tint. Examined under a high magnifying power, these opaque points present the appearance of small round or oval drops. Their form and position encourage the belief that they are situated, not in the lens fibres, but in the interfibrillar substance. According to Liebreich,[3] from whom the above account is borrowed, this form of cataract is frequently, perhaps, indeed, generally, overlooked.

3. *Anterior Polar Cataract.*—A small, round, brilliant, white point, sometimes attaining a diameter of 2 to 2.5 mm., may occupy the centre of the anterior pole of the lens. At times it projects forward into the anterior chamber, and is then known as pyramidal cataract. Often there is a faint central corneal opacity in these cases, and then, according to Arlt, the rationale of the formation of this kind of opacity becomes evident. An intra-uterine central ulcer of the cornea is followed by perforation, the aqueous escapes, the lens comes forward into contact with the cornea, and a portion of the exudation, caused by the ulcer, adheres to the anterior capsule. When the ulcer heals and the anterior chamber is reestablished, the lens recedes to its original position, car-

rying with it the acquired opacity. It is contended by some observers that simple corneal inflammation, unattended by perforation, may also act as a cause.

4. *Posterior Polar Cataract.*—This is a stationary opacity, rarely as small as the smallest examples of the kind just described, situated at the posterior pole of the lens. Its outline may be round and defined; or it may send out striæ of opacity in different directions. It will generally be found to be associated with a persisting hyaloid artery.

5. *Total Congenital Cataract.*—This may differ in no respect from the soft cataract of the young, which is next to be described. But it is more frequently liquid, or else shrunken, and is very apt to be adherent to the iris. The capsule in such cases may be abnormally thickened. These cataracts are always double, and very frequently hereditary.

Soft Cataract of the Young.—The nucleus of the lens is rarely defined before the thirtieth year. Between thirty and forty there is, in the majority of cases, a small nucleus. After forty it is seldom absent. Cataract occurring in a lens devoid of nucleus is always soft. It commences sometimes in the shape of a general grayish opacity, at other times in the form of points or long striæ, in the external cortical layers, and advances with comparative rapidity until the whole lens becomes clouded. It is in this form of cataract that the swelling of the crystalline, already alluded to, is most marked; the iris during this stage being thrown well in advance of its normal plane, and the movements of the pupil becoming restricted in comparison with those of the other eye. An operation at this time is apt to be followed by iritis, and should hence be avoided. Entire liquefaction may subsequently take place, the whole of the lens taking on the color of milk, or of milk mixed with water. As has been said, soft cataract may develop very rapidly. It may, moreover, be confined to one eye, and depend on either a general or a local cause, the nature of which may readily be determined. An example of the first is the

Diabetic Cataract.—As the soft cataract of early life is so often confined to one eye, the simultaneous affection of both lenses at this period would lead us to suspect a constitutional origin, particularly the existence of diabetes mellitus, and to examine the urine for sugar. This form of cataract may occur at any age, and, in the case of the young, progress with great rapidity. It resembles other cases of soft cataract in all respects, except that, according to some observers, traces of sugar are to be found in the lens. The prognosis of the operation is, of course, somewhat modified by the presence of so serious a disease, but need not necessarily be regarded as unfavorable, many cases making a rapid and uncomplicated recovery of sight. It has been claimed[4] that the use of the waters of Carlsbad has been observed to arrest diabetic cataract, and even to cause its complete disappearance.

Cataract Occurring in Connection with Separation of the Retina, Retinitis Pigmentosa, or Disease of the Choroid.—Here we have undoubtedly to do with a local impairment of nutrition; and, of all these causes, the former is the most frequent. The cataract exhibits no peculiarity of appearance. Its cause must be inferred from the fact that it is monocular, that the vision of this eye had been considerably impaired before its appearance, and from the functional examination which reveals a diminished or extinct perception of light in one part of the field, generally the upper. In retinitis pigmentosa the opacity commences as a round spot at the posterior pole of the lens, from which radii shoot out toward the periphery. The anterior portion of the lens subsequently becomes similarly affected, but total opacity does not occur.

Traumatic Cataract.—The transparency of the lens depends on the integrity of its investing capsule. This may be ruptured by a contusion of the eye, or wounded by the penetration of a foreign body or of a sharp instrument. The aqueous humor then comes into immediate contact with the lens, which imbibes it, swells, and becomes opaque. When the capsular wound is very small it may again close, and the opacity remain confined to the contiguous portion of the lens. But more frequently the swollen cortical substance protrudes from and itself widens the capsular wound, thus exposing fresh portions of the lens and ending in its general obscuration. As they protrude into the anterior chamber these masses may be absorbed, and finally the whole cataract thus be removed. But more generally, unless the pupil be at once artificially dilated, the pressure takes place against the iris, which inflames and renders necessary the operative removal of the opaque body.

Senile Cataract.—Under this form we understand the opacity of the cortical substance of a lens, the nucleus of which with advancing years has both separated and hardened. It is necessary to a proper understanding of the subject to bear in mind the probability that only the cortical layers become actually opaque, and that there is no essential difference, in the transparency of the nucleus, between the eye of an aged person who has always had good sight, and the eye of one who has become blind from senile cataract.[5] No precise age can be assigned as that at which this form properly begins, so much variation is there in different individuals as regards the separation and hardening of the nucleus. In general it may be stated that senile cataract is most apt to occur after the fiftieth year. Testing the transparency of the crystalline, in people who have passed this age, the observer is often struck by the appearance of a series of short bifurcating linear opacities, ranged around the periphery of the lens. They may be the most numerous in either the upper or the lower segment, or even extend around its entire periphery. The practical point concerning them is that, though their appearance is always to be regarded as suspicious, they are not necessarily an indication of advancing cataract. They may either remain unaltered for years, or they may increase at once in number and extent. In the former case they are simply a senile change, analogous to the arcus senilis of the cornea; in the latter they justify the diagnosis of incipient cataract. They must be carefully observed, and the patient is not to be alarmed with a positive diagnosis of disease unless they are found to be increasing.

Becker[6] gives the *résumé* of the various stages of senile cataract and their proper nomenclature. As long as there are a few opaque striæ discernible in the periphery only, or in exceptional cases before or behind the nucleus, we speak of incipient cataract. If the opacity of the cortical substance has advanced, the expression unripe cataract is used. There is no absolute line to be drawn between these two, save that the cataract is to be regarded as incipient so long as the greater part of the cortical substance is transparent; as unripe when opaque cortical substance prevails. When the opacity of the cortical is complete the cataract is designated ripe. Oblique illumination then reveals no transparent portion, and no red reflex appears when the ophthalmoscopic mirror is used. The posterior portion of the lens is now, of course, invisible, but it ordinarily keeps pace in these changes with the anterior, and may be assumed to be in the same state.

Senile cataract generally affects both eyes, but is developed later in one than in the other. The fact that the eye last affected furnishes the better result has already been alluded to. That the tendency to this disease is hereditary has been abundantly demonstrated. The popular notions that the left eye is more apt to be first affected than the right, and that more men than women are the subjects of cataract, rest on no reliable foundation.

Absolute maturity of the senile cataract is not always to be waited for, or indeed invariably expected. In certain cases the complete affection of the cortical progresses with extreme slowness; vision in each eye may have fallen off to such an extent that reading and writing are no longer practicable, and the patient even finds it impossible to go about alone in strange localities, or those with which he is imperfectly familiar. Failure of sight continues to progress, but can be made out with certainty only by comparing the vision at long intervals of time. Meanwhile age creeps on and the general health, affected, perhaps, by both moral and physical causes, commences to give way. In other cases progress in the formation of the cataract comes to an absolute standstill. The sclerosis of the nucleus may be complete, the cortical substance partially opaque, admitting a considerable red reflex, or perhaps even an imperfect view of the fundus to the ophthalmoscope, and months and perhaps years elapse without any change in this condition of things. Ripeness is here evidently not to be expected, and surgical interference, either directly or after the operative production of maturity, is wholly justifiable.

Black Cataract.—This name is applied to those rare cases in which the sclerosis of the nucleus goes on uninterruptedly and extends up to the capsule. Although occupied by a ripe cataract, the pupil appears black, even when oblique illumination is used. Cortical substance is completely wanting, and the whole lens is converted into one hypertrophied nucleus. This condition is of most infrequent occurrence.

Capsular Cataract.—Deposits on the capsule from without have already been alluded to. Primary affections of the capsule itself, the formation of opacities in its proper substance, are extremely rare. As careful an observer as Fuchs states that all so-called capsular opacities are deposits externally. The capsule itself invariably retaining its transparency, capsular cataract ordinarily occurs as one of the changes consequent on hypermaturity of an ordinary cataract.

Final Changes in an Over-ripe Cataract.—Inflammation in the lens, caused by this state of things, may bring about the formation of capsular opacities. The cortical substance may undergo partial absorption, this producing some improvement in vision and leading to a diminution in size of the lens. It may become liquid, and the nucleus, no longer supported, may sink to the bottom of the intracapsular space. The capsule sometimes thickens and becomes studded with crystals of cholesterin. The whole cataract may become cretaceous, or, under very exceptional circumstances, even osseous. In the former case extensive adherences with the iris may exist.

TREATMENT OF CATARACT.—*Medical Treatment.*—In view of the great advances made in the diagnosis and treatment of diseases of the eye during the present generation, as well as of the earnest efforts that are still being made in all directions to further ophthalmological science, it would indeed be hazardous to assume that no local application or general medication to affect the progress of cataract will ever be discovered. None the less must it be firmly asserted that, at the present day, we possess no means whatever of preventing the formation of the disease. Numberless remedies have been tried in the past, but have all proved inefficacious, and at the present day none but charlatans assert their ability to cure cataract without an operation. Some administer nostrums, others make topical applications, while others again extol the virtues of electricity; the result in every instance being the same. If the cases of reported cure be thoroughly sifted, it will be found that by far the larger proportion are based on a mistaken diagnosis; that in many instances the process has simply come to a standstill; while in a small number of eyes the lens has either undergone spontaneous dislocation, or else the swelling of the crystalline has been so unusually great as to rupture its capsule and lead to total absorption. Opacities of the layer of intracapsular cells may wholly disappear, and traumatic cloudiness of a portion of the lens may regain some degree of transparency. It is also a well-known fact that diabetic cataract may vary directly with the progress of the disease.

2. *Surgical Treatment.*—This consists in reopening a path for the rays of light to reach the retina, either by the side of the existing obstruction (iridectomy) or by its absolute removal. The latter may be effected in one of three ways: The cataract may be left in the eye, but be pushed aside from the axis of vision (reclination, depression); it may be caused to undergo absorption by being brought in direct contact with the aqueous humor (discission); or it may be bodily removed from the eye through an opening made for the purpose (extraction).

General Considerations.—The indication for an operation for cataract is a probable improvement in vision, combined with safety to the general health of the individual. The two preliminary questions, therefore, to be settled are, first, as to whether a careful examination of the condition and functions of the eye renders it likely that the cataract can be successfully removed; and second, whether the general health is likely to be injuriously affected by the excitement attending the operation, or the subsequent confinement that may be necessary.

As a rule it is undesirable to operate on a teething child, a pregnant woman, or one who is menstruating or about to do so. The general condition of the patient should be carefully inquired into and the prognosis modified if any general disease like diabetes or Bright's disease be present, and it is yet deemed desirable to proceed with the operation. If the patient is fresh from a journey, a day or two's rest should be allowed. If the operation takes place away from home, a sufficient time should be afforded the individual to familiarize himself with his new surroundings. On the continent of Europe there is quite a general agreement among ophthalmic surgeons that serious operations, like the extraction of cataract, which entail a lengthened convalescence, should be performed away from home; generally in the private rooms attached to the hospital with which the surgeon happens to be connected. An establishment especially arranged for the purpose offers advantages of light, ventilation, quiet, and skilled attendance, with which no ordinary private house can compete. There is, moreover, a freedom from care and anxiety that can rarely be secured at home. For the first day or two, relations and friends being excluded, there can be no allusion to exciting topics or consultation on household cares. Distance from the latter is found to induce, with the head of a family, a feeling of repose that close proximity would go far to destroy.

The long-received notion that the spring and fall are the best seasons for cataract operations was undoubtedly based on the fact that these were the times of year which the peripatetic oculists, who formerly infested the community, found most convenient for travelling. In the United States the extreme heat that may prevail during the months of July, August, and September might exert an unfavorable effect on a protracted convalescence, and therefore renders these months less eligible than those in which the weather is generally cooler.

Should one eye be operated on when the other is entirely normal? Assuming the cataract to have been successfully removed, there are certain undeniable advantages in the association of such an eye with a normal one. Although the lens is wanting and the refraction of the two eyes thus radically different, binocular vision is often enjoyed. When this is not possible, double vision does not necessarily arise, as the patient learns to abstract from the image furnished by the imperfect eye, and to rely on the sound one for accurate perception. Even then he has a larger visual field than if he had only one eye, a better estimation of distance, and appreciation of solidity. He is no longer blind on one side, and, when moving about, avoids accidents to which he would otherwise be liable. With the young, therefore, such an operation is always to be encouraged, both for these reasons and, in the case of females, for those of a cosmetic nature. But with the aged different considerations must prevail. The operation, with them, is neither as simple nor as safe, and the after-treatment is much more prolonged. The interruption in the usual habits of an elderly person, the shutting him up in a dark room, changing his diet, and depriving him for a fortnight of the air and exercise on which he is dependent, may exert a serious influence on his health. While in youth it is, therefore, advisable to operate on a single eye, the maxim in age should be never to touch a cataract on one eye until the other begins to be affected, and then to delay as little as possible, bearing in mind the fact that the longer the operation is deferred the older will be the patient, and the greater the depressing effect exerted on his morale by impending and advancing blindness.

Patients are often encouraged by their home advisers to wait until both eyes are fully affected, in order that both may be operated on at the same time. While the simpler cataract operations may undoubtedly, under ordinary circumstances, be performed in the young on each eye at one time, without incurring unwarrantable risk, the extraction of senile cataract on both eyes simultaneously is unjustifiable, save in the most exceptional cases. And this for the following reasons: If one eye only be operated on, the symptoms which follow, and the way and manner in which the eye rallies from or, in extreme cases, sinks under the violence inflicted on it, guide us materially in what we are to do for the other eye, and teach us to adopt such precautions, or so to modify our method, as to give the patient a better chance of sight, and to save him from the dangers to which our ignorance of his idiosyncrasies exposed him the first time. Again, a patient or his attendants, being little used to such delicate operations, may be imprudent, transgress our positive directions, and consequently lose the eye. If both eyes have been operated on, his only chance is gone. If, however, one only has been touched, he will learn wisdom with experience, and insure success by being more careful the second time.

It is true that the refusal of the surgeon to operate on both eyes at the same time often practically results in but a single operation being performed. After the confinement of a fortnight in a darkened room the average patient may well shrink from a repetition of his experience, or fear its effect on the general health. Many people have not the time to give to the second operation, or the means of meeting its attendant expense. These are, however, minor considerations, and are not to be weighed in the balance with those which have been brought forward to show the superior safety of operating on but one eye at a time, in all cases of senile cataract.

The Result of the Operation for Cataract.—In the most favorable cases the obstruction may be entirely removed from the axis of vision and full sight acquired, its acuteness being quite equal to the normal standard. Under such circumstances all the eye has lost is the power of accommodation, which must be met by the use of glasses of different strengths for different purposes, or by shifting the interval between the glass habitually worn and the eye.

But not always is the result thus successful. Portions of the lens may remain behind in the intracapsular space, clots of blood may be imperfectly absorbed, or inflammation may cause a proliferation of opaque substance on the face of the capsule; the whole sometimes becoming more or less adherent to the edge of the pupil. This forms what is known as secondary cataract, and demands in its turn an appropriate operation, or the loss of the eye may be entire, the inflammation following the original operative interference being so violent as to cause entire opacity of the cornea, or even wasting away of the eye itself. An irritable stump, thus left, may give rise to sympathetic ophthalmia of the remaining eye, a condition of things which may also be brought about by the antecedent inflammation. This result is fortunately extremely rare, and may not once occur in the experience of a lifetime.

Antiseptic Measures.—Before entering on the description of the various operations for cataract, the question of antiseptic measures is naturally to be considered.

Our attempts at sterilization apply to the patient, the operator, and the instruments, the latter being by far the most fertile sources of infection. The surgeon and his assistants should wear special outer garments. Those made of linen, freshly washed and ironed, answer a useful purpose. The hands are to be thoroughly washed in warm water and with soap, scrubbed with a nail brush and afterward dipped in a four-per-cent. carbolic solution, or else in one of corrosive sublimate (1 to 2,000). As far as the patient is concerned the vicinity of the eye and the edges of the lids are to be carefully washed with soap and water, after which a sterilized pad, soaked in the same solution of corrosive, large enough to cover the eye and its immediate neighborhood, may be applied and left in place until the moment for operating arrives. After using the anæsthetic the conjunctival sac may be washed out with sterilized water, or a weak solution of corrosive (1 to 5,000). It seems a matter of comparative indifference which of these methods is employed, as so momentary an application will have but little effect on any bacteria that may be present. Particular attention is to be paid to the state of the lachrymal sac, and its freedom from infectious secretion is positively to be ascertained.

It is in regard to the sterilization of the instruments and the manner of bringing this about that the greatest diversity of practice has perhaps obtained and the most different methods have been adopted. The delicate instruments used in ophthalmic surgery must naturally be handled with greater care than many of those employed on other parts of the body. Immersion in solutions of corrosive sublimate corrodes metal and ruins the edge of the knife. A four-per-cent. solution of carbolic acid has been proved insufficient to destroy the suppurative germs. To bring about this result with certainty, probably no agent is more efficacious than heat, in either the dry or the moist form. Yet each of these has its disadvantages. Steaming or boiling, the latter in simple water or in alkaline solution, is apt to be followed by rusting. Baking at a temperature of 150° C., continued for an hour or more, is absolutely certain. But all instruments subjected to this must be made with metal handles in place of ivory or bone, and it is doubtful whether the fine knives used for the corneal section would, after such baking, retain a perfect edge. Many operators, influenced by the above considerations, content themselves with immersing their instruments, previously thoroughly cleansed, in a bath of absolute alcohol before the operation, and withdrawing them one by one as they are wanted for use.

But experience shows that knives thus immersed suffer appreciably in their cutting properties. It is the custom of the writer to have a small vessel of boiling water brought to the bedside, just before the operation is commenced, and to immerse the blade of the cataract knife and the point of the keratome in it for a few seconds.

Anæsthesia.—General anæsthesia, brought about by ether or chloroform, has now, in the vast majority of cases, given place to the local anæsthesia induced by cocaine. This agent was introduced and its properties were explained by Koller in 1884. Its use has become general. Employed ordinarily in the form of the hydrochlorate, and in a solution varying from two to five per cent. in strength, its contact with the eye brings about anæsthesia of the conjunctiva and cornea, coming on in from one to two minutes and lasting some ten minutes. In an operation for the extraction of cataract it should be applied two or three times. It is well to remember that the sensitiveness of the iris is not materially affected by the cocaine, and to prepare the patient for a certain amount of pain in case an iridectomy forms part of the operation. Besides producing anæsthesia of the surface of the eyeball, cocaine brings about other changes. It contracts the blood-vessels of the iris, and thus gives rise to a temporary mydriasis; it empties also the conjunctival blood-vessels. On account of this double effect the annoying hemorrhage that sometimes so much embarrasses the performance of an extraction is much less likely to occur. There is also noticed a wider opening of the lids and a lessened tendency to wink. Finally, the intra-ocular pressure becomes slightly reduced.

If the surgeon finds it impracticable to prepare a sterilized solution of cocaine on the spot, he may use a 1 to 5,000 solution of sublimate as a menstruum. It is best to prepare the patient for a slight smarting sensation when the first application is made to the eye. This very rapidly disappears.

A one-per-cent. solution of holocain gives a local anæsthesia quite as effective as that produced by cocaine. It causes an even greater degree of insensibility of the iris. It gives rise to no constitutional symptoms, as is sometimes the case with cocaine. It has the advantage of being distinctly bactericidal in its action. But it does not arrest hemorrhage as does cocaine. The solution of holocain should be made in porcelain, never in glass, and keeps indefinitely.

There are other local anæsthetics, none of which seems to deserve comparison with the two above described.

Discission.—In this operation the removal of the cataract is sought to be effected by wounding the anterior capsule, and bringing the aqueous humor in direct contact with the lens; the object being to cause its complete absorption without impairing the transparency of its capsular envelope. The former object will not be attained if the consistence of the cataract be too great or its sclerosis too marked. The latter cannot be secured if the operation be followed by serious inflammation, due to the excessive effect produced by its performance, and which would follow a want of care in proportioning the size of the opening in the capsule to the amount of toleration the eye is capable of exhibiting.

The substance of the lens, brought into direct contact with the aqueous humor, imbibes it just as a sponge soaks up water. Like the sponge it swells, and then slowly crumbles away and dissolves. It is the tendency to swell, and thus exert mechanical pressure on the contiguous parts that constitutes the main danger of the operation; and it is the merit of von Graefe to have first insisted on the necessity of proportioning the opening in the capsule to the amount of lenticular swelling the eye can safely sustain. The rapidity of absorption depends on the age of the individual, being most active with the young. The amount of swelling varies according to the maturity of the cataract and the period at which it is attacked.

The course of normal absorption is as follows: First the edges of the capsular wound retract; then the lens substance begins to swell and protrude into the anterior chamber. Oblique illumination brings it into relief as a grayish plug, blocking the opening left by the needle. In some cases the whole lens gradually swells and presses forward until the anterior chamber is completely blocked; in others the process is more gradual, and each successive protrusion slowly undergoes absorption. It first grows larger, then more transparent, next its surface becomes irregular, is gradually eaten away, and the mass finally disappears. Sometimes small fragments are successively detached, fall down, and are dissolved. One mass succeeds another, protrudes, and goes through the same process until the whole lens has been removed.[7] It is evident that the aqueous humor that accomplishes this task is too insignificant in amount at any one time to do more than a small portion of it, and must hence be steadily undergoing both excretion and renewal. As will be seen later on, Arlt bases on this fact a recommendation to hasten absorption, in cases in which it is progressing with unusual slowness, by occasionally doing paracentesis of the anterior chamber, and thus artificially removing the saturated aqueous.

We have thus traced the course of an operation followed by normal absorption. But all cases do not progress thus favorably. The lens may imbibe the aqueous humor too freely, and swell with a rapidity that causes destructive pressure to be inflicted on the surrounding parts. The pupil may then be seen to contract, the ciliary redness that naturally is present in some degree during so active a process as absorption becomes alarmingly great, and even conjunctival chemosis may ensue. The iris becomes discolored, the eye waters, intolerance of light is felt, local pain becomes severe, radiating in every direction, and finally, unless proper measures of relief are taken, vision may gradually be extinguished by the development of secondary glaucoma, the legitimate consequence of the great increase in pressure. As has been observed by von Graefe, these symptoms are almost exclusively met with in the young, the lens in elderly people rarely imbibing aqueous humor so rapidly or to such a dangerous extent.

To avoid iritis caused by direct pressure of the swollen cortical mass on the iris itself, it is most necessary that the pupil be fully dilated before the operation, and kept so during the whole of the absorption. An important contraindication to the performance of simple discission is therefore the failure of the pupil to respond to the action of a mydriatic. Cases in which the pupil cannot be readily and largely dilated are not those in which the performance of a simple discission is at all admissible, and this test should always be employed before deciding on the character of the operation to be selected.

This operation is admissible in all simple lenticular cataracts of early life, up to the twenty-fifth or thirtieth year. It is especially to be employed in the case of infants, both because the size of the opening in the eye is so trivial as to obviate the necessity of attention to the healing process, and because at this age absorption takes place with such rapidity that the pressure of the swollen cortical mass is but little to be dreaded. It is also advisable to do discission in lamellar cataract that occupies so large an area as to render an iridectomy useless, and when the patient has not passed the age of twenty. In the traumatic cataract of early life, where the extent of the original injury has been so limited as to produce an effect but slowly progressive, this operation may be used to hasten ripeness of the cataract, and to promote rapidity of absorption. For nearly a generation it has been justly abandoned in all cases of senile cataract.

Instruments; Preparation of the Patient; Method of Operation.—The instruments needed for the performance of discission are the ordinary spring speculum, fixation forceps, and stop-needle. The latter (Fig. 1151), the perfection of which we owe to the inventive genius of Sir William Bowman, ought to be extremely slender, with a cutting edge of not more than a millimetre in extent. Its shaft should so completely fill the wound made by its point as to prevent the escape of the aqueous humor by its side during the operation. This would cause the lens to fall forward against the cornea, and embarrass the use of the needle. Lower down the instrument is furnished with a shoulder, which renders its penetration into the eye, beyond a certain depth, impossible.

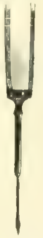
Fig. 1151.—Discission Needle.

The patient may sit in a chair, facing the operator, unless anæsthesia be employed, when the recumbent position is of course preferable. The objections to the use of anæsthetics during the extraction of cataract do not apply to the operation of discission. Although the pain is not excessive, the subjects are young and consequently nervous; and, as will be seen, it is important that sudden spasmodic attempts to close the eye should not be made. Narcosis is therefore generally desirable, and its practice renders an assistant, for the most part, unnecessary. The pupil, as has already been stated, should be fully under the influence of atropine. The lids being separated by the introduction of the speculum, the eye is grasped by the fixation forceps at a point opposite to that selected for the introduction of the needle, generally over the insertion of the internal rectus. The point of the needle is now applied to the cornea midway between its centre and periphery, downward and outward, and made to transfix it in the direction of the posterior pole of the lens, and perpendicular to the corneal surface, so as not to penetrate it obliquely. As soon as the needle has passed in up to its neck the handle is lowered and the point carried forward until it touches the anterior capsule at a point outward from its centre, perhaps midway between that and its periphery. Raising the handle, and now regarding the instrument as a lever, the fulcrum of which is where it passes through the cornea, the operator makes its point descend along the face of the capsule, and inflicts on this membrane a vertical wound, some 2 mm. in extent. Lowering the handle now, and at the same time slightly withdrawing the needle so that its point is no longer in contact with the capsule, he again pushes it forward, directing this time to a point on the nasal side of the horizontal meridian of the capsule, midway between its centre and periphery, and then making it inflict on its face a horizontal wound, precisely similar to the vertical one already made. The needle is then gently and steadily withdrawn, being held in the same position as when it entered the eye. At the instant of withdrawal it is well for the operator, if unassisted, to release the fixation forceps and raise the speculum slightly from off the eye, with his left hand, so that no pressure may be made upon it. The aqueous humor is thus less likely to escape, and the pupil consequently remains dilated. For a similar reason the removal of the speculum must be conducted with great care, and without touching the eyeball. If anæsthesia remain profound no spasmodic closure of the lids will occur at this juncture, and no aqueous be lost.

Great care must be taken not to bruise or crush the cornea by too forcible manipulation of the needle, and to this end it should be simply allowed to rest lightly on the cornea, at its point of passage through it. The incisions should be as nearly as possible at right angles with each other, and should not be extended as far as the equator of the lens, in order to avoid too rapid swelling, as well as adherences between capsule and iris (Arlt). Should the needle slip out of the eye before the operation is completed it may be reintroduced, unless the aqueous has escaped, in which latter case the operation must be desisted from until the aqueous has again collected.

When a single operation proves sufficient the average time necessary for the absorption of the lens is ten weeks. But the process does not always go on uninterruptedly. A small capsular opening may be so blocked by the protruding fragment of lens as to cut off the access of aqueous humor to the parts behind, and absorption of this fragment may be followed by closure of the wound. In such cases the operation must be repeated and larger incisions made. Occasional paracentesis of the anterior chamber greatly promotes absorption, but would be needed only in exceptional cases.

After-Treatment.—A bandage is of doubtful utility. With very young children it encourages weeping, and its moral effect is at any age depressing. A shade, covering both eyes, may be given, and the room be dimly lighted. The pupil must be kept permanently dilated with atropine, a half-per-cent. solution of which should be applied three or four times a day, except in the case of very young children, in whom there is danger that symptoms of intoxication may manifest themselves. The atropine is to be continued as long as the absorption is going on, though after the first it need not be applied so frequently. If symptoms of reaction occur, as indicated by watering, undue ciliary redness, and local pain, strict quiet is to be enjoined and cold compresses are to be applied to the eye. If they continue, one or more leeches may be applied on the temple, care being used to apply the leeches as far as possible from the eye itself. The bowels are to be kept open. If no relief is experienced, and the symptoms grow more pronounced; if tension increase, chemosis appear, and pain become more severe, it will probably be necessary to open the anterior chamber and evacuate the aqueous humor through an opening sufficiently large to allow any detached fragments of lens substance to escape at the same time. In extreme cases it may be necessary to practise linear extraction of the whole lens, with or without iridectomy.

Modified Discission.—In cases in which the pupil fails to respond promptly or thoroughly to atropine, or in which other indications of a tendency to inflammation are present, the operation of discission is rendered much more likely to succeed by the performance of an iridectomy three or four weeks before the use of the needle is undertaken. The excision of iris should be done upward, and the piece removed be of good size, and extend up to the ciliary edge of this membrane. The increased area thus given to the pupil lessens the number of points of contact between the cortical substance and the iris, renders contraction of the pupil much less to be dreaded, and diminishes the danger of secondary glaucoma. This last complication is not infrequently the cause of the blindness that sometimes follows discission, and the likelihood of its occurrence varies directly with the advance in age of the individual. In the performance of this modified discission Wecker[8] advises that the capsule be opened principally within the area of the new pupil, thus limiting the precipitation of fragments of the crystalline into the anterior chamber, and regulating the advance of the absorption. When the upper portion of the lens has thus been removed, its lower part may more advantageously be attacked.

With regard to the operation of discission in general, it may safely be stated that, allowing the cases to be properly selected, and due care used in its performance, it is the safest and surest method at our command. Total loss of the eye is, under these circumstances, excessively rare.

In former times yet another method was practised, having for its object the removal of the cataract from the axis of vision without taking it out of the eye, namely, the operation of *reclination* or depression. A needle specially adapted to the purpose was passed in through the sclerotic, and used to tear the opaque lens away from its attachments, and lay it at the bottom of the eye. False in principle, and often disastrous in result, leading to restoration of vision in but from fifty to sixty per cent. of the cases in which it was used, this operation has justly been abandoned, and is, therefore, no longer to be described among the methods in use at the present day. It is still, however, of interest from a historical point of view, and will be alluded to at length in a subsequent portion of this article. For the present we proceed to the consideration of those operations which rest on the principle of the total removal of the cataract from the eye, and commence with the one involving the smallest solution of continuity, the method of

SUCTION.—This may be considered the operation of aspiration applied to cataract. Throughout the series of operations that have for their object the extraction of the lens, one of the great dangers to be apprehended is that connected with the healing of the wound necessarily inflicted on the eye. The larger this is, the greater the danger of inflammatory and other complications. Such accidents are least to be dreaded after a discission, they are appreciable with a linear extraction, and, as will be seen, the risk becomes greatest of all in the case of flap extraction. A method which should bodily and entirely remove the cataract through the smallest possible opening avoids at once the dangers attendant on slow absorption and the chance of the imperfect healing of a large wound. The operation of suction fulfils both these conditions. It is accomplished by means of an instrument formed from the glass barrel of an ordinary subcutaneous injection syringe, to one extremity of which is attached a piece of rubber tubing ending in a mouth-piece, while on the other end is a bent hollow needle of large size, open at its extremity. This needle is passed through a small opening in the cornea and anterior capsule, the air in the tube is then exhausted, and the soft cataract substance flows in to take its place.

This, in brief, is extraction by suction. It is a method of great antiquity. Evidence exists of its having been used in the East in the fourth century, and frequent subsequent references are made to it in ophthalmic literature. In 1846 it was revived by Laugier, who made his opening in the sclera, and introduced the point of the suction needle through the posterior capsule. Teale, in 1864, published a drawing of an improved instrument, and recommended a method of operating which is substantially that in use at the present day. Since then most authors refer to the proceeding. Yet it cannot be said to have ever yet found its way into general favor, or to have met with the appreciation which, in a certain class of cases, it really deserves.

It is probable that extraction by suction would have attained greater popularity had the indications for its performance been better understood and the class of cases to which alone it was applicable, more sharply defined. Authors, for example, report instances of subsequent inflammation and failure in lamellar cataract, a form to which this operation is wholly inapplicable. It should never be employed save in cases of known soft or liquid cataract, and in the traumatic form of the disease occurring in persons under the age of thirty. And in the latter class some time should be allowed to intervene between the accident and the operation, several days, or even a week, being, if possible, suffered to elapse, in order that the whole of the lens substance may become thoroughly opaque. The instruments needed are a spring speculum, fixation forceps, bent broad needle, and the suction apparatus (Fig. 1152). To the form of this latter especial attention is directed, as the figure here given differs materially from the instrument described by Mr. Teale, and generally used abroad. Our barrel is shorter, and slightly less in diameter than the English; the neck of the hollow needle, at its lower end, exactly fits the opening made by the broad needle, and the opening is across the extremity (Fig. 1153) instead of being on its front face. The rubber tube that connects with the mouth-piece has a coil of light wire running the entire length of its interior. Each of these modifications offers a corresponding advantage, as will be seen when the operation comes to be described; and the greater favor it has met with in America may with justice be attributed, at least in part, to the superiority of the native instrument.*

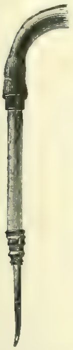
FIG. 1152.—Suction Apparatus. (Reduced in size.)

Operation.—This is by no means devoid of pain, and an anæsthetic may be used to advantage. The pupil should of course be fully dilated. The surgeon, sitting behind the patient's head, fixes the eye with forceps, and makes, with a bent broad needle, an oblique incision through the cornea at a point outward from its centre and about three-fifths of the distance between that and the sclero-corneal junction; preferably in the outer-upper quadrant on the right side, in the upper-inner on the left. The point of the needle is carried across the anterior chamber, made to penetrate the anterior capsule, and then withdrawn. If this be carefully done, all the aqueous humor may be retained. The suction instrument is now introduced, its orifice being directed upward, and its point brought in contact with the lens substance. This being done, the air is withdrawn by the mouth, the force applied being perhaps similar to that used in smoking a well-made cigar. The neck of the hollow needle exactly fitting the wound, the instrument may be rotated, advanced and in part withdrawn, without loss of aqueous; and the important advantage is thus gained of not coming in contact with and bruising the iris. After the lens matter has filled the instrument it may be withdrawn, cleansed, and if necessary again inserted, though it will be better if this can be avoided. While the suction is going on the wire in the flexible tube prevents this from doubling on itself, and thus obstructing the draught of air. The shape of the aperture of the needle enables the surgeon to search for separate portions of lens matter, and apply the point directly to them, while they are drawn in with a much greater facility than would be the case with an opening differently situated. The operation completed, the instrument is withdrawn and a bandage applied. It is ordinarily unnecessary to keep the patient in bed more than twenty-four hours, or even to retain a bandage for a longer period. A shade may be worn over both eyes until all redness has disappeared, but the amount of reaction is often astonishingly slight. A fear has been expressed lest vitreous should be drawn into the tube. This seldom happens, especially with the instrument here described, the length having been curtailed and the calibre reduced in order to get less atmospheric pressure and thus avoid the accident.

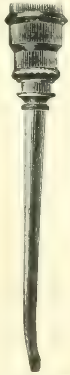
FIG. 1153.—Magnified Picture of Point of Suction Instrument.

As regards the results of the suction operation, the reports of the Massachusetts Charitable Eye and Ear Infirmary for the last eleven years show the performance of one hundred and seven operations by suction. In some of the reports the results of that year are given, in others the number of operations is simply stated; no selection in either case having been made. In the 65 recorded cases the results are as follows: full success, 46; partial, 18; loss, 1. In 5 of these cases vision was perfect, that is ten-tenths.

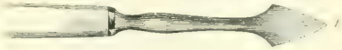
FIG. 1154.—Straight Lance Knife.

Simple Linear Extraction.—In the operation just described the opaque lens substance was removed through a minute opening, by being made to flow into a vacuum. In that now under consideration the same thing is effected through a larger opening and by pressure. It is used for the same class of cases, viz., liquid, soft, and traumatic cataracts, in those who have not yet passed the age of twenty-five; and is moreover applicable to shrunken or rudimentary cataracts, on which suction would have no effect. And it is to be borne in mind that, while extraction by suction has never yet found universal favor, or been much practised out of England and America, linear extraction has long and generally been regarded as an operation both justifiable and valuable.

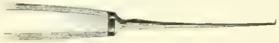
FIG. 1155.—Cystitome.

The instruments used in its performance are a spring speculum, fixation forceps, straight lance knife, cystitome, and Daviel spoon (Figs. 1154, 1155, 1156). Iris forceps and fine scissors should be in readiness, in case it is found necessary to excise a prolapse. The forceps may also have to be used where a shrunken cataract is to be removed.

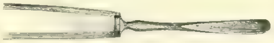
FIG. 1156.—Daviel Spoon.

The patient is to be in a recumbent position, and to have the pupil fully dilated. Anæsthesia, either general or local, may advantageously be employed. Having grasped, with the fixation forceps, a fold of conjunctiva to the inside of the cornea, the operator makes an incision with the lance knife in the corneal substance, perpendicular to the surface of this membrane, and at a point on its horizontal meridian either midway between its centre and outer edge or, if nearer the latter, at least 2 mm. removed from it. As soon as the point of the instrument has entered the anterior chamber its direction is changed, and the knife is pushed forward in a plane parallel to that of the iris. A wound of from 6 to 8 mm. having been made, the lance knife is slowly and steadily withdrawn, care being taken to keep it always in the same plane, and thus avoid the too rapid escape of the aqueous, an event which would be followed by the contraction of the pupil. Owing to the triangular shape of the knife it is evident that the inner wound must be smaller than the outer, and it is well to attempt to equalize the two by directing the point of the lance either a little upward or a little downward, as it is withdrawn. But it should never be rotated, and should exert as little pressure as possible.

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* This instrument is the one in use at the Massachusetts Charitable Eye and Ear Infirmary, and the modifications here detailed are largely due to the late Dr. Robert Willard.

If the capsule is opaque, or if we are seeking to extract a shrunken cataract, a small sharp hook, or the iris forceps, may now be introduced through the wound, and the capsule or cataract seized and withdrawn. If, however, we are dealing with an ordinary soft cataract, the next step is the opening of the capsule. The cystitome is passed through the wound by gently pressing it against the outer edge, its cutting edge being held parallel with the face of the cornea. Once in the anterior chamber its flat is made to glide over the front of the cataract until the point at which it is desired to commence the capsular opening is reached. The handle of the instrument is then turned so as to have the edge face the capsule, on which a wound is inflicted by the withdrawal of the cystitome in its new position, care being taken that the handle is again rotated just before the edge of the pupil is reached, so as to avoid wounding the iris. If the cataract be very soft the cortical mass will now begin to escape and rapidly fill the anterior chamber. Many operators content themselves with this single opening, which is quite sufficient when a Graefe's cystitome is used, as a triangular flap is thus torn from the capsule. (This is the instrument given in Fig. 1158.) If a straight cut be made in the capsule it must be supplemented by another running at a slightly different angle; a large capsular opening being essential to the entire removal of the cataract, as well as the prevention of secondary capsular opacity. Many of the cataracts removed by this operation are very thin, and care must be used not to sink the point of the cystitome so deeply in the mass as to wound the posterior capsule.

The opaque lens is next to be removed by pressure. At this stage of the operation it is better to take out the spring speculum, and to raise the upper lid with the thumb of the left hand. The rounded back of the Daviel spoon is now to be applied to the portion of the cornea that remains between the opening and the periphery of this membrane, and the wound so made to gape slightly. Pressure thus judiciously applied, aided by a slight amount of rubbing in the same region, will often cause the expulsion of the lens substance. But if this takes place very slowly, or ceases altogether, counter pressure may be applied through the upper lid, at the opposite side of the cornea, by means of the thumb that is used to hold the lid in place. The pressure and counter pressure thus made must be used alternately, with a gentle rocking motion, until the last portion of the cataract has emerged and the pupil has taken on a uniformly black appearance.

If the nucleus should turn out larger or more consistent than was expected, and hence refuse to pass through the wound, the Daviel spoon may be gently introduced and an attempt made to extract it, either whole or piecemeal. Care must be taken not to rupture the posterior capsule, as the escape of vitreous both complicates and retards convalescence, besides at once interrupting the operation if it occurs in its early stages. The fragments of the cataract are then often driven apart and away from the wound, and cannot in many cases be collected or removed without entailing a dangerous loss of the vitreous humor. If a prolapse of the iris takes place, it may be allowed to remain until the cataract has been removed, when it will often return spontaneously, or can be made to do so by gently rubbing through the closed lids. But if it obstinately retains its position, it must be at once excised. The healing of this into the wound might not only alter the corneal curve, but prove a source of irritation by the traction it would exert, thus giving rise to serious trouble. It might also increase the density of the scar. The more peripheric the wound the greater the danger of prolapse.

Fragments of the cataract remaining in the pupil imbibe aqueous humor, swell, and may thus give rise to grave inflammatory symptoms; causing iritis, and delaying or preventing the healing of the wound. It may not always be possible to effect a complete removal of these portions, owing to the size of the wound, the consistence of the cataract, or the lodgment of the smaller pieces in remote situations inaccessible to ordinary pressure. As Arlt, whose account of the operation has largely here been followed,[9] justly observes, simple linear extraction is by no means as universally applicable in cases of soft cataract as the first accounts of the operation, given by von Graefe, would lead one to suppose.

After-Treatment.—After having instilled a drop of a solution of atropine, and ascertained that the lips of the wound are in proper coaptation, as well as that no remains of the cataract or coagulated blood are to be found in the conjunctival sac, the eye is closed, and a simple compressive bandage applied over each eye, thus securing absolute repose. An elliptical piece of linen, soaked in the weak sublimate solution, 1 to 5,000, is first laid on each eye. The orbital cavity is then evenly filled with corrosive cotton applied in small tufts, as evenly distributed as possible. These, as well as the bandage itself, should of course have been carefully sterilized. The hand, passed over the summit of the heap, should not distinguish the prominence of the eyeball. This process having been completed, the whole mass should be made to exert gentle pressure on the eye by means of a bandage, which may be either a simple cotton or flannel roller, or, still better, the so-called Liebreich bandage. The simplest form of this well-known appliance is a cotton band, about 30 cm. long and 6 wide, knit in small alternate squares, the threads in adjacent squares running at right angles to each other. Long tapes are attached to each of the four corners. The peculiar construction of this band insures a considerable degree of elasticity, and it is held in place over the eyes by securing the tapes behind the head, the two upper being tied above, the two lower below the crown. It is well to remove the bandage some eight hours after the operation, gently sponge the outer surface of the lids, and apply a fresh dressing. If no pain, swelling, or excessive lachrymation be present, nothing will be gained by opening and examining the eye. At the end of twenty-four hours, during which time the patient has been kept in a recumbent position, it will be well to open the eye and instil a drop of a solution of atropine. The bandage is now to be changed once a day for three or four days, when it may be removed altogether and a shade over both eyes substituted. After the first day the patient may leave his bed. As the redness slowly disappears, more light may be admitted and moderate use of the eyes allowed. It must be remembered that the wound requires several days to consolidate, and that during this time it is no difficult thing to separate its edges.

Local pain, redness, and increasing photophobia are evidences of excessive reaction. The bandage may then be removed and cold compresses substituted, leeches applied to the temple, and even subcutaneous injections of morphine made in the same region if the suffering is considerable. The bowels must be kept open. If none of these measures give relief, the aqueous humor is to be evacuated; better, according to Arlt, through a peripheric puncture, than by reopening the original wound. In spite of all these precautions, iridocyclitis may ensue, and even give rise to sympathetic affection of the remaining eye. Such cases are, happily, very infrequent.

We now come to the consideration of one of the most important operations on the eye—that for the removal of senile cataract. It is proper to consider it immediately after linear extraction, just described, inasmuch as the most approved method now in use is that of peripheric linear extraction; a proceeding somewhat allied to the foregoing, and the general adoption of which has resulted in the virtual abandonment of flap extraction, so universally practised less than a generation ago. Before, however, commencing the discussion of this method, it is desirable to consider one or two plans that have been recently proposed for the artificial ripening of senile cataracts, the formation of which proceeds with unusual slowness. This delay in the growth of cataract has been alluded to in an earlier portion of this article. In many cases, as was there stated, it proves a serious misfortune to the patient. All power of using either eye on near objects may be gone; it may even be difficult for the individual to move about unattended, especially in strange places, and he may thus become a burden to his family. Meanwhile the cortical substance still retains a portion of its transparency. The best years of life are passing away, or those dependent on the patient may be reduced to poverty in consequence of his inability to continue their support. Something ought, under such circumstances, to be done; and the alternative to removing an unripe cataract is the artificial production of maturity.

Two methods alone are regarded at the present day as offering ordinary chances of safety. The first is that proposed by Professor Förster, of Breslau, in 1881, and consists in the performance of an iridectomy upward, together with the rubbing of the cornea, over the face of the lens, with the angle of a strabismus hook. There being no anterior chamber, the pressure is directly applied to the lens through the intervening cornea. "The effect in ripening the cataract," says Förster, "is frequently to interrupt the entire reflex from the fundus within six days. In from six to eight weeks at farthest the cataract entirely matures." At the time of his bringing out this method he had practised it for five years and in about one hundred and fifty cases. He considered it chiefly applicable in cases of senile cataract with hard nucleus, and partially opaque cortical; but advised that it be not employed in posterior polar cataract. He warned against using a pressure, on the one hand, so light as not to hasten the cortical opacity, and on the other so extreme as to rupture the zonula. Recently Dr. Charles Bull, of New York, has given an analysis of thirty cases, in which he employed this method. In addition to the rupture of the zonula, which may be produced by too strong pressure, he alludes to another consequence, "a striated or radiating opacity of the cornea, which seems to be confined to the anterior layers, frequently remains for a long period, and fades out but slowly." He also recommends a rotatory rubbing or massage. Slight iritis has been observed to follow the operation by several observers, including the present writer. In Dr. Bull's series, iritis occurred five times. All his cases were successful, vision ranging between $\frac{20}{40}$ and $\frac{20}{100}$ in all but three, in which it was under $\frac{20}{100}$. The average duration of the confinement, after the first operation, was five days.

The second method of artificially ripening a cataract was alluded to by Förster when he brought forward the operation above described. It had been, he said, observed by Snellen that a simple iridectomy would sometimes hasten the progress of lenticular opacity. This he confirmed from his own experience. In a recent publication Jakobson again calls attention to this fact. "It is well known," he says, "that, up to within a short time, people half blind were obliged for months, and sometimes even for years, to rely on extraneous aid. By the performance of an iridectomy we are now enabled to offer them a prospect of sight within three months."[10] He goes on to say that his experience with Förster's operation has been unfortunate, iritis and inflammatory thickening of the anterior capsule having occurred in his practice. An iridectomy alone, in cases of unripe cataract, has been followed by inflammatory reaction, yielding, however, readily to atropine and fomentations.

Of these two methods the second is undeniably safer, as offering less instrumental interference with the eye. It possesses the advantage of being in itself one of the steps in peripheric linear extraction, and its anterior performance leaves just so much less to be done when the cataract is finally removed. The practical objection to it is the fact that it subjects the patient to two operations on the eye, instead of one; two confinements with both eyes bandaged in a darkened chamber. The effect of all this on the general health and morale of the individual will vary in different cases; and therefore renders it impossible to lay down any fixed rule with regard to the propriety of producing artificial maturity. All that can be said is, that in ordinary cases of slow growth, the performance of the additional operation would seem a lesser evil than weary months of waiting for natural ripening.

A few general remarks with regard to the extraction of senile cataract may fitly precede the descriptions of the various operations devised for this purpose. And first with regard to the induction of anæsthesia. On this point there has been much difference of opinion, its use having been comparatively general in this country, but far less frequent on the continent of Europe. The experience of the present writer has convinced him that the state of anæsthesia throws appreciable obstacles in the way of a successful extraction, and that its regular employment tends to diminish the number of favorable results that would otherwise be obtained. This opinion is based on several grounds. The necessity of fasting before the administration of the ether or chloroform, and the inability to retain nourishment for some time afterward, have a depressing effect, especially on the aged and feeble. The amount of congestion induced in many by the inhalation of ether encourages hemorrhage and embarrasses the performance of the operation. The patient's ability to move his eye at will being lost during anæsthesia, every needed motion has to be given to the eye by traction with the fixation forceps, inflicting a fresh bruise at every application, and sometimes leading to a loss of vitreous. The collapse due to anæsthesia annuls tension and renders the removal of cortical fragments proportionally difficult. After the operation the patient is incapable of giving information with regard to the clearness of his acquired sight, and moreover loses the moral support of having once seen, a support well calculated to cheer the succeeding dark days of convalescence. The surgeon, too, is thus deprived of important knowledge with regard to the result of the efforts he has made to clear the pupil. Finally, the nausea that so often comes on as the effect of the ether passes off, the retching and vomiting, that sometimes endure for hours, can only have an injurious effect on an eye so recently laid open, besides rendering the patient unable to take nourishment and depressing his morale. To ascertain whether these objections were more than theoretical, two series of cases were operated on, a certain number with and an equal number without ether. Each series consisted of one hundred, and the great difference in the percentage of success was wholly in favor of the non-administration of the anæsthetic.

This discussion, however, becomes less important in view of the fact that, save in the most exceptional cases, local anæsthesia amply suffices. It has already been described.

A very important question next arises, as to whether the eye shall be prepared for the removal of the cataract by the dilatation of the pupil, as was formerly the usual custom. This practice was generally continued after the operation of flap extraction had given way to that introduced by von Graefe. The arguments for the instillation of atropine before extraction were, in brief, that there would be more room for the knife in its passage across the anterior chamber; that its point would be less likely to catch in the iris, and a wound or dialysis would consequently more seldom follow; and that the secondary dilatation that ensues on the re-establishment of the anterior chamber would tend to keep the edge of the iris clear of any fragments of cortical substance that might remain behind, and lessen the likelihood of a closed pupil and of a secondary cataract. It began, however, by degrees to be found that, where mydriasis had not been induced, it was easier to replace the iris after extraction, and thus prevent its healing into the corners of the wound. To prevent this accident it was even advised to apply a solution of eserine, after the lens was removed.[11] Acting on this hint, the present writer has been in the habit of applying the eserine an hour before the operation. At the time of its performance there is then found a considerable contraction of the pupil, which does not in the least interfere with extraction, and which yields when the anterior chamber is re-established. It then exerts on the iris a degree of traction that reduces to a minimum the danger of its healing into the corners of the wound, and would even seem to render this complication less frequent than formerly. This contraction of the pupil readily yields to atropine, should it be found necessary to employ it during the after-treatment. Eserin. salicylat., rubbed up with vaseline in the strength of one per cent., will be found a convenient preparation to use on account of its being less affected by time than the ordinary solution. The application of eserine is sometimes followed by slight temporary pain, and is hence contraindicated at the time of the operation. Its use has been objected to on the ground that the tendency to a loss of vitreous might be increased, but this theory has been proved unfounded.

The advantages of operating on senile cataract in an establishment especially arranged for the purpose have already been alluded to. Should this course be adopted, it is well to have the patient occupy his room the night before the operation is performed. A certain amount of acquaintance with the bed, the surroundings, and the attendants is thus acquired before the bandage that prevents all use of the eyes for several days has been finally applied. Another advantage is that there may often be met, in the same place, some convalescent who has already passed through the operation, and who can be brought in contact with the intending patient. A few words of encouragement from such an individual will often do more to dispel apprehension and establish confidence than anything coming from the surgeon himself.

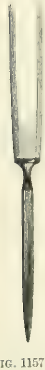
FIG. 1157. Graefe Knife.

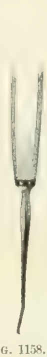
FIG. 1158. Cystitome.

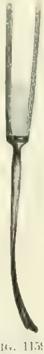
FIG. 1159. Rubber Spoon.

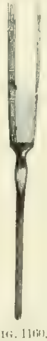
FIG. 1160. Rubber Spatula.

If a trained and experienced nurse be present, the services of a professional assistant may readily be dispensed with. The patient awaits the surgeon in bed and undressed. As the bandage to be applied after the operation is monocular, the eye that is not to be touched is closed by several short strips of isinglass plaster, crossing each other. A short preliminary drill in turning the eye in any given direction, without any corresponding movement of the head, will be found of much use; the patient being directed to roll the eye up, down, or to either side at the request of the operator; being also cautioned, the while, to avoid straining, and to breathe easily and naturally. In the case of very deaf people it is well to arrange a little code of signals in advance, a tap on the forehead being understood to mean a direction to look up, one on the chin to look down. Under ordinary circumstances the duty of the nurse is confined to handing the iced sponges as they are needed, and supporting the head while the bandage is being applied.

Peripheric Linear Extraction.—This is commonly known as the method of von Graefe. The instruments needed are a spring speculum, fixation forceps, elevator, Graefe extraction knife (Fig. 1158), cystitome and rubber spoon (Figs. 1158 and 1159), Daviel spoon, iris forceps and scissors, and a small, straight, flexible rubber spatula (Fig. 1160). A few soft compresses, floating in ice water, are also required, as well as corrosive cotton bandages, etc.

The surgeon stands at the head of the bed, and should be able to operate on the right eye with the right hand, on the left with the left. Local anæsthesia having been fully brought about, he introduces the spring speculum and locks it in place, being careful not to stretch the lids to a distressing extent. Requesting the patient to look up, he firmly grasps the eye with the fixation forceps, a little below the cornea. Holding the knife with its edge up, he now proceeds to make the cut. The accomplishment of this is not without its difficulties, and demands a careful description. It can best be understood by reference to the following diagram (Fig. 1161), taken from Arlt.[12] The knife is entered, with its blade up, at the point *a*, 1.5 mm. from the corneal edge, and 2 mm. below a tangent to the upper corneal periphery on the temporal side, and directed at first toward the point *b*, situated downward and inward from the pupil. Having been carried steadily forward some 6 to 8 mm. in the direction of this point, the handle is lowered, the point of the knife directed to that of counter-puncture *c*, pushed forward, and made to emerge at this place. The wound to be inflicted will thus be some 12 mm. in length. It is better now to remove the fixation forceps, thus avoiding the danger of undue pressure, and to request the patient to look down. The wound is completed by a sawing movement of the knife, alternately advancing and withdrawing it a little, directing its cutting edge toward the point at or just behind the upper corneal edge, where it is intended that it should emerge (Fig. 1162). No attempt should be made to divide the conjunctiva until the scleral cut is complete. The blade of the knife may then still be directed upward, but a little outward, and a conjunctival flap formed some 2 or 3 mm. in height. Raising the handle of the knife abruptly, from the temple, is advised by Arlt as facilitating this. It will be seen that this is not strictly a linear wound, as originally intended by von Graefe, so that the title of the operation is, to some extent, a misnomer. But the conjunctival flap can be formed only when the cut is made as above described, and the advantages of this flap as a protection to the scleral wound are at once evident. A curved cut is, moreover, longer than a linear one. The external cut being 12 mm. in length the inner one would measure from 9 to 10 mm., and as the diameter of the lens rarely exceeds 9 mm., there is sufficient room for its emergence.

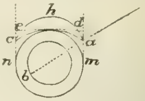

FIG. 1161.—Ideal Peripheric Linear Cut. (Corneal diameter 12 mm.) *a m*.*c n*, tangents to the horizontal diameter *m n*; *d e*, tangent to the vertical diameter; *a*, point of puncture; *a*, *b*, line of direction of back of knife at time of puncture; *c*, point of counter-puncture; *a*, *d*, *h*, *e*, *c*, course of conjunctival wound; *a*, *c*, course of cornea-scleral wound on outer surface of sclera.

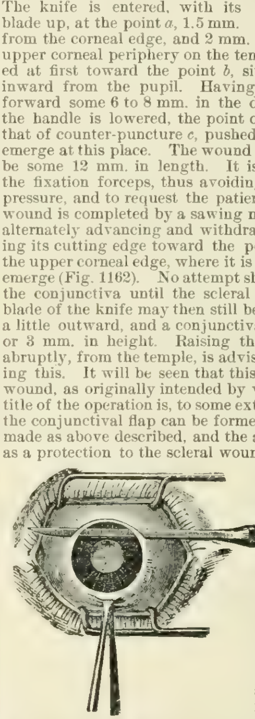
FIG. 1162.—(From Michel's "Lehrbuch.")

Should there be considerable hemorrhage from the conjunctival flap or the scleral wound, filling the anterior chamber and obscuring the view of the iris, it is better temporarily to remove the speculum and hold soft iced compresses in gentle contact with the closed lids. In a few minutes the bleeding will cease, the eye can be again opened, the speculum reinserted, and the coagulated blood removed with iris forceps. Ordinarily, however, we proceed directly to the second step in the operation, the iridectomy.

It is better to accomplish this without resuming fixation. The iris scissors are taken in the right hand, the forceps in the left. The patient being directed to look down, the conjunctival flap is lifted with the forceps and laid backward over the cornea. The iris is now seized at its pupillary edge, the forceps being well carried over toward the end of the wound at the operator's right, withdrawn, lifted forward, and a straight cut, or rather split, made in its tissue from the pupillary to the ciliary edge; it is then drawn over toward the opposite corner of the wound, being divided as it is thus drawn by repeated strokes of the scissors, and the piece finally completely excised by passing the scissors on the other side of the forceps and repeating the first cut from the pupillary edge backward. A coloboma of from 4 to 8 mm. in extent is thus formed. Professor Arlt, whose method of executing the iridectomy is here closely followed, advises strongly against tearing the iris from its ciliary attachment, rather than cutting it as just described. By following the latter course hemorrhage is far less likely to occur. The edges of the coloboma are to converge toward the pupil, and if considerable iris tissue is left in the corners of the wound it is to be separately excised. At this stage it is often advised to replace small prolapses of iris at the wound angles with the rubber spatula; but as the delivery of the lens is almost certain to be followed by their recurrence, it is better to wait until this has taken place and the pupil been cleared. Hemorrhage may now, if at all embarrassing, be controlled in the manner formerly described.

Opening of the Capsule.—Careful watch should be kept over the amount of pressure which the spring speculum exerts on the eye. If this organ be unusually prominent, or the straining of the patient excessive, the speculum may be slightly lifted off by the unoccupied hand of the operator, or even removed altogether and an elevator substituted. Fixation, which has been dispensed with since the performance of the first step in the operation, is not again to be employed.

A word, in passing, on this subject. Sufficient stress has hardly ever been laid on the injurious effect on the eye of prolonged fixation. Each grasp of so delicate and sensitive a member with this rude instrument (toothed or serrated forceps) causes ciliary injection and acts as a local bruise, the multiplication of which may well tend to complicate or retard the healing process. Becker's remarks, in this connection, are most instructive. He says: "Seizure of the conjunctiva bulbi, either alone or with the addition of the tendon of the rectus inferior, is ordinarily looked upon with indifference. And yet an appreciable injury is only too often thus inflicted. Though the fixation forceps be used in the most careful manner, the point which they seize becomes for days the seat of a defined redness. If the teeth of the forceps are very sharp, the patient restless, and the conjunctiva fragile, as is often the case with the aged, bleeding follows, and the tissue may even tear." Speaking later of the wrenching given the cornea, ciliary body, and iris, by drawing down the eye after the cut has been completed, he observes: "The more or less perfect manner in which these secondary injuries are avoided goes very far to determine the varying success met with by operators of otherwise equal skill."[13]

The cystitome is introduced flatwise, at one corner of the wound, pushed forward until its extremity comes opposite the lower edge of the pupil, then turned with its cutting edge toward the face of the capsule, and drawn gently upward to the edge of the wound. To secure a free opening it is better to introduce it a second time, apply it at a point on one side of that first selected, and again draw it upward in a line diverging from the previous one. Care should be taken to exert little or no pressure backward, for fear of causing dislocation of the lens. If the eye be deep-set, it will be necessary to bend the stem of the instrument at an angle some 7 mm. from its point. Should the anterior chamber be filled with blood that cannot be cleared away, the cystitome must still be used in the region of the supposed pupil; but it is well, under such circumstances, to restrict somewhat its excursions.

Arlt prefers, to the ordinary cystitome of von Graefe, a sharp iris hook with a flexible stem. In cases in which the capsule is opaque there is no doubt but that this membrane may be better seized with such an instrument and brought to the edge of the wound, where it can be removed with scissors. The use of the hook demands, however, special dexterity on the part of the operator.

Delivery of the Lens.—We come now to one of the most critical portions of the operation, during which the escape of vitreous is most to be dreaded. Should this accident happen in the shape of a sudden gush, it is desirable immediately to close the eye. The withdrawal of the spring speculum takes time, as it has to be first unlocked and then carefully removed from under the two lids separately, and without tilting over the cartilage of the upper lid, a common occurrence. It has, therefore, long been the practice of the writer to remove the speculum before proceeding to the delivery of the lens, and either to raise the upper lid with the forefinger of the left hand or else to lift it by means of a simple elevator, which can be instantly slipped out if occasion demands. To effect the removal of the lens, the patient is first directed to look down and to keep his gaze fixed in this direction. Much difficulty is occasionally experienced in keeping this up, the eye exhibiting a tendency to roll upward. In such cases it may be found advantageous to place one of the patient's hands outside the bedclothes and then request him to look persistently in its direction. It may serve to fix his attention if the nurse smartly taps the hand from time to time. By getting the patient to look down we are able to exert pressure against the eye through the lower lid, and thus to escape the necessity of bringing any instrument in direct contact with the eyeball. The convexity of the Daviel spoon or the back of a large hard-rubber spoon is laid against the outside of the lower lid; pressed gently, at first backward and then upward, and then, if the lens shows a tendency to emerge and the edge presents itself at the wound, used to assist its expulsion by gently rubbing upward. Should the eye roll up, the pressure must, of course, be applied directly to the eyeball. The moment half the lens has passed through the wound, pressure is to be lessened, but not omitted, until the entire crystalline has emerged. If, in spite of judicious pressure, the lens fails to present itself at the wound, or, having presented itself, to advance, the first thing to do is to repeat the opening of the capsule, a delicate and often difficult proceedure.

The lens once removed, the lids may be suffered to close and the patient to rest a few moments. Compresses dipped in cold water may be applied to the eye externally and frequently changed. When the eye is again opened, the pupil is to be carefully examined. If lens fragments or coagula occupy its area, they may be expelled by repeating the manœuvre for the removal of the lens, rubbing upward while the patient looks down. They should, however, first be collected in the centre of the pupil by closing the eye and rubbing gently over its convexity, in a circular direction, with the point of the forefinger. If the cloudiness is evidently due to an opaque capsule, it is better to leave it alone and trust for its removal to a secondary operation. Incising it with a cystitome or sharp hook, as is sometimes advised, would lead to an escape forward of vitreous, and might complicate recovery. When the pupil is apparently clear, vision must be tested. If the answers are unsatisfactory, if the patient cannot count or name the fingers held before him, his head of course being turned away from the light, the rubbing must be renewed. No inspection of the pupil by the surgeon gives information comparable to the actual exercise of vision by the patient himself; nor should the bandage be applied until the sight seems reasonably good. If, indeed, there were no other reason for this course, the advantage of the moral effect produced on the patient can scarcely be over-rated.

The corners of the wound must now be carefully examined to see whether iris tissue has become incarcerated there. Should this be the case the flat rubber spatula may be used for its replacement, pushing it first out of the wound, and then gently patting or spreading it out in its proper position. The importance of thus clearing the wound, as well as the danger of allowing a prolapse of iris to heal into the cut, can scarcely be exaggerated. As soon as the anterior chamber has become re-established the influence of the eserine will again be asserted, and offer an additional safeguard against this accident. After the remains of the cataract and coagulated blood have been removed from about the wound and from the conjunctival sac, by means of the edge of a bit of soft linen or a similar fragment of sponge, the conjunctival flap is to be carefully lifted into place by the iris forceps and the eye closed; care being taken that the upper lid, in its descent, does not reverse the flap.

Accidents during the Operation.—The most dreaded is the escape of vitreous. This may be due to a faulty position of the wound, to intra-ocular disease resulting in abnormal fluidity of this humor, or to the employment of undue pressure in expelling the cataract. While the moderate loss of vitreous may be simply followed by a lengthened and irritable convalescence, its escape in any considerable quantity is apt to entail retinal separation, choroidal disease, or even general inflammation of the eyeball. The accident is characterized by the appearance in the wound of a transparent viscid fluid. If it occurs immediately after the completion of the cut, the iris is to be quickly excised. The removal of the lens has now to be effected, with as little further escape of the humor as possible. Any pressure would, of course, increase this tendency. No attempt is to be made to open the capsule, and the lens is to be removed by traction with an appropriate instrument. For this purpose the writer has always employed Critchett's scoop (Fig. 1163), an instrument that combines lightness with flexibility, and effects reliable traction; occupying the while comparatively little space in the eye and distending the edge of the pupil but slightly. Its employment demands a quick eye and a steady hand. If the eye is deep-set the instrument is to be somewhat bent, and is then to be introduced with the patient looking down, and in such a direction that its edge slips behind the periphery of the lens. It is now quickly passed down until its lower rim is thought to be opposite the base of the lens, the handle is then to be sharply but gently inclined backward, and the instrument at the same time drawn up and out of the eye, bringing the lens with it. This manœuvre bears a distant resemblance to that by which a lever pries a stone out of the ground. A gush of vitreous generally occurs at the instant the lens emerges; the eye is, therefore, to be instantly closed and dressings are to be applied. The lens is thus extracted in its capsule, and subsequent vision is apt to be unusually clear and distinct in cases in which a good recovery is made.

FIG. 1163.—Critchett's Scoop.

Where, after the operation, vitreous simply projects at the edge of the wound, separating its lips, some advise excision of the prolapsed portion with fine sharp scissors. It is better practice to leave it alone and trust to the influence of the pressure bandage to effect its subsidence. Should this prolapse occur after the nucleus has passed out, but before the pupil has been thoroughly freed from cortical substance, the operator finds himself between the two horns of a dilemma. The lesser evil is to close the eye at once and trust to time for the absorption of the remaining cortical. Bleeding into the anterior chamber may occur during either of the several stages of the operation, and has already been alluded to.

Bandages and After-Treatment.—An elliptical patch of soft linen is to be laid on the eye, and the orbital hollow filled with small tufts of corrosive cotton, as was described in connection with the after-treatment of linear extraction. In the present case, however, one eye is already closed by strips of plaster, and the bandage is, therefore, to be monocular. Every surgeon has his favorite form; the writer prefers a flannel roller, 4.5 mm. in width, and long enough to encircle the head three times alternately with a similar number of rising turns over the eye, one fold overlapping the other, the whole affording moderate compression and support. If the weather be very warm, gauze may be advantageously substituted for flannel. The bandage once applied, the room is to be darkened and the patient left in quiet for a few hours. He is to avoid turning over on the side of the operated eye. Should he desire to vary his position by lying on the opposite side, he is to lift his head slightly from the pillow, so as to avoid dragging on the bandage. Should the operation have been performed in the morning, the patient may be seen again in the course of the afternoon. At this, as well as subsequent visits, it is well to avoid letting in daylight, on account of the great change in illumination that may unexpectedly occur. The sudden emergence of the sun from behind a cloud may unexpectedly flood the room with light and distress an eye used to entire darkness. A single candle is the best and most easily managed source of illumination. By the time of this visit the pad next the eye will generally be found more or less stiff and uncomfortable, having become soaked with blood and tears. It should, therefore, be changed. The outside of the lids may be gently bathed with a soft compress dipped in lukewarm water, but they are on no account to be separated unless something unusual has occurred. To this end the patient is to be cautioned, before the bandage is removed, not to open his eye, but to keep it softly closed. The feeling of soreness and the sensation of a foreign body between the lids will by this time have probably died away. The dressing having been renewed a bed-chair may be brought in, and the patient allowed to rest himself by sitting up in bed for a short time. Later in the evening a dose of chloral may be given. It is well to have a watcher in the room the first one or two nights.

At the visit on the following day, if the case be progressing favorably, the lids are again to be washed and the bandage is to be renewed, but the eye is not to be opened. From this time forth the bandage may be changed once in twenty-four hours. By the third day the plaster used to close the other eye will ordinarily be found to have become quite stiff, and its edges will have rolled in, causing some discomfort. It is therefore to be soaked off. A Liebreich bandage may now be used over both eyes, instead of the flannel roller. By this time, too, the patient may sit up in an easy chair and have his bed made. He is to spend an increasing portion of every day out of bed until he occupies the latter only at night. The diet is to be nutritious, but all chewing should be strictly avoided. The room should still be kept darkened.

There is, among ophthalmic surgeons, a great diversity of opinion as to when the lids should first be separated and the eye examined. Arlt lays down no fixed rule, but intimates that this may occur at the second visit, twenty-four hours after the operation; and even sooner if necessary. The experience of the present writer has led him to adopt a different course. He gradually came to find that the eye did quite as well if the lids were allowed to remain closed two or even three days. As time went on, a new fact forced itself repeatedly on his notice; that in certain cases, in which the healing process was interrupted by inflammatory complications, the first pain, lachrymation, or discharge followed accurately on the first separation of the lids, however carefully managed and however hasty the examination. The case might have been doing perfectly well for three or four days; no swelling of the lids, lachrymation, or undue discharge being present, or the slightest pain experienced; the eye might then, for the first time, be opened and rapidly surveyed by a weak light, no lens being used and no trial of the vision made, and yet within a few hours pain would occur and marked symptoms of inflammation be present. This happened so frequently that it became impossible not to connect the examination and the inflammation as cause and effect. Acting on this belief he kept prolonging the time that he allowed the eye to remain unopened, and now he rarely makes the first examination before the morning of the eighth day. At this time it is often remarkable to see how little evidence of the operation is present, a trifling redness in the immediate vicinity of the wound being sometimes all there is to be seen. This redness, slight at first, will be observed for several days steadily to increase before it begins to disappear.

The above course of treatment is applicable only to cases in which the healing process may be presumed to be progressing normally. The writer believes that the longer the examination is deferred the more likely the patient is to do well, and he bases this opinion simply on experience. Of course, numerous theoretical objections to such a method might be alleged. It could be argued that the secretions of the wound, and the blood left in the conjunctival sac, being unable to escape, might decompose and act as sources of infection. This and other objections might be brought forward. To those urging them the writer simply suggests a fair trial of the plan itself, believing that they will in the end themselves find that the longer they leave the wound undisturbed, in contact with and guarded by the covering provided by nature, thus sealed and protected from any germs of contagion with which the atmosphere may be infected, and which the exposure of a single instant might attract, the more success they will meet with in the after-treatment of extraction.

One caution must here be given. While, as a rule, both eyes should remain covered until the eighth day, it must be borne in mind that some aged and weak people are peculiarly sensitive to the combined effects of darkness and solitude, and may be attacked by a form of delirium which renders them difficult to control. If this occurs the sound eye may be sooner uncovered, perhaps on the fourth or fifth day. After the removal of the bandage from both eyes, light may gradually be admitted into the room, the patient wearing a shade, or a pair of blue or smoked protective glasses curved to cover the eye more effectually, the so-called "coquille" spectacles. Several days should still be suffered to elapse before the patient is discharged from the immediate supervision of the surgeon. During this time the pupil is to be carefully watched, and atropine used if it evinces a tendency to contract, or if its area is at all occupied by remains of blood or cortical substance. Fifteen days after the performance of the operation the patient may ordinarily go to his own home, but he is to wear the protective glasses for a month or six weeks longer, and to avoid exposure to bright light, or any use of the eyes. When six weeks have elapsed after the removal of the cataract he may cautiously commence the use of the appropriate glasses.

We have thus far considered a case of uncomplicated recovery, and must be prepared to deal with departures from this type, they being unfortunately not infrequent. Unusual duration of the pain connected with the operation itself may often be relieved by removing the bandage and washing the outside of the eye with ice-water. If it still continues, the edges of the lids may be examined to see if any lashes have become inverted, and the under lid may be slightly drawn downward to allow the escape of any accumulation of tears. Cold compresses may be alternated with the compressive bandage, or even a morphine injection may be made in the temple. In extreme cases the linen pad next the eye may be thoroughly wet with atropine, although the use of a mydriatic should, if possible, be dispensed with for several days after the operation, on account of the danger of prolapse into the corners of the wound. If the pain continues, or even if, in the absence of pain, the lids swell and lachrymation or discharge be present, the eye must be opened and carefully examined by oblique light, the candle being held to one side and its rays concentrated on the eye by means of a convex lens of short focus. Iritis, if present, is to be treated by leeches to the temple, atropine, and the alternation of the bandage with warm, but not hot, fomentations. If there are signs of suppuration in the wound, the fomentations are to be even more regularly applied, twenty minutes at a time, every four hours, and the bandage is to be kept on in the interval, being applied even more tightly. The eye may, moreover, be bathed with the following antiseptic solution: Salicylate of sodium, 1 gm.; boracic acid, 3 gm.; dissolve in warm water, 100 gm.; stir well, cool slowly, and strain.

Compresses wet with this solution may be constantly kept on the eye; if the inflammatory process continues and no benefit is derived from the fomentations and the bandage, quinine should be given in large doses, and the general health supported with generous diet and stimulants. The previous history and habits of every patient are to be well weighed by the surgeon; those addicted to the free use of stimulants would incur great danger of an unfavorable result if these were suddenly suppressed. Should any form of opium have been habitually indulged in, the customary ration must be allowed.

If thirty-six or forty-eight hours pass without accident it is probable that the eye will be saved, and some measure of sight retained. Iritis is still possible, but, if properly treated, is unlikely to result in blindness. One great danger to be guarded against during convalescence is a sudden blow on the eye, inflicted by the patient himself during sleep or carelessly when awake. This may cause bleeding into the anterior chamber, or even rupture of the wound. The blood may be absorbed or the wound heal under a prolonged application of the bandage, and no ultimate ill effect be experienced; or a state of chronic irritation may follow, ending in closure of the pupil and necessitating the performance of a secondary operation. Or, at the worst, irido-cyclitis may ensue, the pupil closing and the iris being drawn forward until the anterior chamber is obliterated, all perception of light disappearing after weeks of suffering. There are even instances on record of this condition of things causing sympathetic irritation and ultimate loss of the remaining eye. It would be well, therefore, to proceed to enucleation in the case of an eye in this condition, especially if tenderness on pressure exists.

Secondary Operations.—After an ordinary extraction the anterior capsule retracts and leaves the area of the pupil occupied, substantially, by the posterior capsule only, thus exposing any portions of cortical substance that may remain behind to the full action of the aqueous humor. In cases, therefore, in which the cataract was not entirely mature, and in which lens substance as yet clear has escaped notice and been left behind after the operation, it may happen that a pupil which at first appeared clear and black is discovered, on removing the bandage, to be entirely blocked with opaque cortical masses, swollen and pressing forward. These may be absorbed quietly and vision be slowly gained. But they are more apt to give rise to inflammation of the iris, by the mechanical pressure which they exert upon it, and to cause this membrane to contract adhesions with them. After the inflammation subsides we may thus find a pupil contracted, drawn up, and filled with a dense membrane, a so-called secondary cataract. Another form of secondary cataract is the opacity of the capsule or the deposit of opacities on the capsule that sometimes occurs long after the extraction, and that does not appear to be connected with any unusual feature, either of the operation itself or of subsequent convalescence. Patients often return, years after the cataract has been removed, complaining that their vision, originally excellent, has gradually undergone diminution. The power of reading any but the largest type may perhaps have entirely disappeared. The capsular opacities in these cases are often apparently insignificant, hardly visible indeed by oblique illumination. But the ophthalmoscope shows the outline of the optic nerve to be indistinct and distorted; and the mirror alone, particularly that of the binocular instrument, plainly reveals a delicate web of opaque capsule stretched across the pupil, now distinct in one part and now in another, as the handle of the instrument is slightly rotated, and the direction of the reflected light thus changed.

To bring about a return of vision it is necessary to secure a permanent opening in this capsular screen. Numerous devices have been imagined for the accomplishment of this. Discission with a single needle is rarely sufficient. The introduction of a hook, through a small opening made for this purpose at the edge of the cornea, enables us to tear away a piece of the capsule, but may give rise to a dangerous amount of traction, and thus result in irritation or inflammation of the ciliary body. To avoid this, Bowman devised the so-called "double-needle operation." Two ordinary discission needles are used; one is taken in the left hand, is passed through the middle of the inner half of the cornea, and made to penetrate the thickened capsule; the other is held in the right hand, passed through a corresponding point in the middle of the outer half of the cornea, and introduced into the capsule by the side of the first. One needle is then held still while the other tears from it, or else each is made to tear the capsule in an opposite direction. In either case a *point d'appui* is gained, and the strain no longer comes on the ciliary body. Among other ingenious operations of this class is one devised by Dr. C. R. Agnew, of New York. Passing his first needle through cornea and capsule, as in Bowman's operation, he makes an incision with a broad needle at the opposite corneal edge, being careful in withdrawing this needle to allow no escape of aqueous by its side. He then passes through the opening a sharp and flexible hook, engages its point in the capsule just where it is pierced by the stop-needle, and tears a hole from this needle which thus acts as a point of support.

Where the pupil is drawn up and filled with tough membrane, or remnants of lens substance enclosed in opaque capsule; where the iris, tightly stretched and thickened by inflammation, obstructs all access of light to the retina, the operations above described are impracticable. Simple iridectomy is rarely resorted to, owing to the difficulty experienced in grasping and withdrawing sufficient iris tissue. Iridotomy, incision of the iris itself, is here to be advised. Wecker's scissors, sometimes used for this purpose, are a pair of short and delicate blades, made to open and shut by the lateral movement of the two sides of the long forceps handle to which they are attached. A lance knife is first passed through cornea and iris, and the scissors are then introduced into the opening in the latter and used to give it increased length, one arm being inserted behind iris and thickened capsule, the other in front of them. If the wound thus made gapes, disclosing a clear black pupil, no further interference is necessary; if not, a second incision is made at an angle to the former one. The included flap may even be withdrawn with iris forceps and excised. Far simpler, and, in the writer's opinion, safer, is the incision of the iris and capsule by means of a narrow Graefe knife passed obliquely through cornea and iris, and made to act as a lever, incising the latter by simply raising or depressing its handle, according as its edge looks up or down, the cornea in this case acting as the fulcrum. By introducing the knife in a new place a second incision may be made at an angle to the former one. Vitreous is much less likely to be lost when iridotomy is done in this manner.

Simple Extraction or Extraction without Iridectomy.—This operation is daily finding its way into more general use. It cannot be said to have supplanted the one just described, as each has its appropriate field. But extraction without iridectomy has become the more popular method, while the old operation is beginning to be confined to a daily diminishing class of selected cases. It might be well to preface the description of the operation by a brief account of its advantages and disadvantages.

The advantages of the non-performance of an iridectomy are simply and concisely stated by Professor Pflüger (*Kl. Monatsblätter für Augenheilkunde,* May, 1892, p. 161). He considers the return to simple extraction to be the greatest improvement in the cataract operation that has occurred for twenty-five years, and for the following reasons:

The conservation of the normal pupil combines optical with antiseptic advantages, in regard to the first part it having been proved that the corneal refractive power is at its best in the centre of that membrane; moreover,

(1) There is no wound of the iris, and hence far less likelihood of a depot for the collection of offensive, that is, infectious material;

(2) There is no bleeding into the anterior chamber, to obscure the subsequent steps of the operation;

(3) The wound is protected by the intact iris from contact with fragments of capsule, the presence of which so often causes slow healing and secondary infection, leading it may be to chronic irido-cyclitis and even to sympathetic affection of the other eye;

(4) There is a certain amount of protection against loss of vitreous;

(5) Pflüger's experience leads him to think, strange as the fact may appear, that there is less danger of secondary glaucoma in the case of a simple extraction.

It is not asserted that the percentage of corneal suppuration is affected by the performance or non-performance of an iridectomy. Stress is laid on the claim that, after successful simple extraction, the excentric vision is better and light better borne. On the other hand, it may be replied that the iridectomy need not be a large one, and that being made directly upward it is largely covered by the upper lid, thus insuring a considerable use of the centre of the cornea.

Furthermore: 1. Considering the extent of the corneal wound, as well as the frequently large solution of continuity of the conjunctiva itself, the additional terrain afforded by the iridectomy for the collection of infectious material would be a matter of small account.

2. Bleeding is reduced to a minimum by the action of the cocaine, and frequently is entirely absent.

3. If prolapse of the iris, or even dislocation of the pupil occurs, the capsular fragments may yet come in contact with the wound, and these capsular fragments, as well as cortical remains, can be both more perfectly detected and thoroughly removed where the area is laid bare by an iridectomy.

4. That the statistics of simple extraction show a lessened percentage of vitreous prolapse, as compared with the Graefe operation, is not as yet universally admitted.

5. The same may be said in regard to the occurrence of glaucoma. The experience of individual operators is here at variance. Dr. Knapp, in 1890, reported three cases of glaucoma as occurring among one hundred simple extractions (*Archives of Ophthalmology,* vol. xix., p. 299).

There are two serious drawbacks to simple extraction:

The first is the difficulty in clearing the pupil of cortical and capsular remains, after the lens has been delivered. It is obvious that, with an iridectomy, there is a larger pupillary area in view and a wider aperture for the extrusion of whatever may occupy it. Moreover, the manœuvres we generally employ for the clearing of the pupil, the tilting and rubbing, tend to maintain, if not to produce, the presence of the iris between the lips of the wound, and to render its ultimate reposition more difficult.

This leads directly up to the main objection to simple extraction, the liability to iris prolapse. This accident is met with in from seven to ten per cent. of all cases of this operation. Its disadvantages are the change thereby wrought in the corneal curve, the dislocation of the pupil, the lengthened convalescence entailed, and the tendency to cystoid cicatrization of the wound. It is most likely to occur in consequence of a sudden motion or injudicious effort on the part of the patient within the first few days after the operation, and may be brought about by the forcible contact of the hand with the eye during sleep. The wound being ruptured, the aqueous humor escapes, and carries with it the iris, which remains incarcerated between the lips of the wound. A sudden sharp pain is sometimes felt and arouses suspicion as to what may have occurred. But there are cases in which no imprudent motion is known to have taken place, and no warning has been sounded, and yet in which the first inspection of the eye, several days after the operation, reveals an extensive iris displacement.

The tendency of the eye to undergo this accident is well illustrated by the statistics of a third series of 100 cataract extractions without iridectomy, published by Dr. Knapp (*Archives of Ophthalmology*, vol. xix., p. 280).

In 7 of these cases iridectomy had to be performed during the operation.

In 2 cases the iris folded itself over the knife and was excised.

In 8 cases prolapse and incarceration of the iris occurred during the healing process.

Eighty-three of these patients therefore recovered with fair, round pupils, 15 either had iridectomy performed or would have been better off had this been done. In a recent letter Dr. Knapp informs me that his confidence in simple extraction is undiminished, and that he employs it in fully 90 per cent. of all his cases.

Performance of Simple Extraction.—The long, narrow knife of von Graefe may be used for the corneal incision, the puncture and counter-puncture being made just above the horizontal meridian of the cornea, in the transparent periphery of this membrane, the apex of the cut alone encroaching on the limbus. This is the course taken by experienced operators like Knapp, who aim at the avoidance of the peripheric section of former years. The capsule opening is made by some at the same time, and with the same knife used in the incision; by others with a special cystitome, and may be central or peripheric, either method having its advocates. Sometimes a piece of the anterior capsule is removed with forceps specially constructed for this purpose. To expel the lens pressure is made at the base of the cornea, through the lower lid, while the upper lip of the wound is at the same time slightly depressed by means of pressure made through the upper lid. After the delivery of the lens, the pupil, if still occupied by fragments of cortical or remains of capsule, may be freed by judicious manipulation, or irrigated with a sterilized solution of boric acid or common salt, either one-half or one per cent. in strength. These solutions should be slightly warmed and but little force used in their introduction. For this reason the syringe originally employed by McKeown will be found less manageable, as well as more difficult to sterilize, than the apparatus of Lippincott (Transactions American Ophthalmological Society, Twenty-seventh Meeting, p. 115), or the "undine" of Wicherkiewicz. The writer has modified the latter instrument by attaching to its large aperture a short rubber tube, ending in a glass mouthpiece. Both hands of the operator are thus left free; he holds the mouthpiece between his teeth, and is enabled at will to modify the pressure to any extent, or even to reverse it and withdraw masses of cortical by suction into the apparatus itself. Solutions of corrosive sublimate are no longer used for irrigation, on account of the corneal opacities they were found occasionally to induce. Care must be taken to keep the opening of the irrigator as far from the pupillary edge as possible, prolapse of the iris being readily encouraged by its too immediate contact with this region. It is at best a clumsy instrument and its use a choice of evils.

After the clearing of the pupil and anterior chamber has been completed the iris must be carefully replaced, there being no better instrument for this purpose than a flat, narrow rubber spatula. If reduction be found impossible, or the iris shows a tendency to fall back into the wound, a small iridectomy must be made on the spot. In any case a solution of eserine (one per cent.) or pilocarpine (two per cent.) should be dropped into the eye before closing it.

It has of late been seriously proposed by certain surgeons that the non-operated eye be left unguarded, that only a light dressing be applied to the other, and that the patient be kept in an undarkened room and allowed much freedom of motion. Good results are claimed from such an absence of treatment. This, if true, would reverse our traditions and revolutionize our practice. But as yet the only evidence in its favor is that of vague assertion, unsupported by definite statistics. Its advocates are at present few.

Iris prolapse being, as has been stated, often due to the sudden escape of the aqueous humor, consequent on a rupture of the corneal wound, an ingenious means of obviating this has been devised by Dr. H. B. Chandler, of Boston, and proposed by him as a modification of the operation. He makes a small opening in the iris in order to allow the free escape of the aqueous, which collects behind this membrane, and claims that this prevents prolapse.

His description of the operation is as follows: "After making a corneal cut, exactly at the cornea-scleral junction, a very small piece of iris, about 1 or 2 mm. from the periphery, is caught up, either by means of a fine iris forceps, with teeth situated on the lower portion of the blade, as near the point as possible, or by means of a sharp hook, the bent portion being at right angles and about 1 mm. long, and gently drawn out, is cut horizontally as close to the gripping instrument as possible; this leaves a small round opening, not more than 1 to 2 mm. in diameter" (*Boston Medical and Surgical Journal*, October 16th, 1890, p. 366).

For two or three days after a simple extraction greater quiet is necessary than is the case when iridectomy has been performed, the patient being cautioned to avoid straining and all sudden exertion. The occurrence of severe pain in the eye, or even a feeling of irritation, such as might proceed from the presence of a foreign body, should arouse suspicion of prolapse. If this comes on within two days after the operation the eye must be opened and the protruding iris reduced or excised. Otherwise it is better to leave it alone until the wound is thoroughly consolidated. After a lapse of several weeks the prolapse, if it shows no signs of flattening, may be excised or cauterized.

And now comes the practical question as to which of these two methods of extraction, the combined or the simple, is to be employed in a given case. In the present state of our knowledge the first thought of the surgeon is undoubtedly a desire to remove the cataract without the mutilation of the eye which accompanies an iridectomy, provided this can be done with safety. It is therefore well to sum up the contraindications to the simple operation. Concerning these, opinions vary, yet it may fairly be conceded that extraction with iridectomy is a safer method when:

(*a*) The patient is well advanced in years.

(*b*) When he is very nervous or restless, impatient of restraint or devoid of self-control, prolapse of the iris being under such circumstances more to be dreaded.

(*c*) When the diameter of the cornea is less than usual, or when the pupil fails to dilate properly under the influence of a mydriatic.

(*d*) When the presence of a tremulous lens, or antecedent disease, gives reason for apprehending fluidity of the vitreous.

(*e*) When posterior synechiæ exist.

(*f*) When prolapse of the iris, occurring during the operation itself, does not admit of reposition.

The exclusive employment of one method of extracting cataract would seem unwise. Each case must be taken on its own merits; its history, the condition of the eye, and the disposition of the patient carefully considered, and the operation selected that seems likely to be followed by the best results. Doubtless a successful simple extraction leaves the eye in a more normal condition, and thus affords a more perfect result. To gain this result the operator requires a maximum of experience and skill, while the patient must be prepared for a somewhat more burdensome convalescence, and must also be willing to incur a slightly increased risk of accident.

It is impossible, in an article like the present, to review all the different operations for the extraction of senile cataract that have been proposed, even within the present generation. Those just described are the ones in general use at the present day, and are considered to furnish, on the whole, a larger percentage of success than all others. There are, however, two methods that have attracted a good deal of attention and found influential advocates. They deserve at least a passing notice. Liebreich's method of extraction is performed as follows, the knife used being similar to that in peripheric linear extraction, only somewhat narrower: The patient is in the recumbent position, the pupil under the influence of atropine. Supposing the right eye to be the one to be operated on, the surgeon stands behind the head of the patient. He raises the upper lid with the forefinger, and steadies the eye by pressing lightly against the sclera with the middle finger of the left hand. The right hand holds the knife, whose back is directed horizontally and backward, while the plane of its blade forms an angle of about forty-five degrees with the horizontal meridian of the eye. The point is made to enter the sclera about 1 mm. away from the edge of the cornea and 2 mm. below its horizontal diameter, and to emerge at a similar point on the opposite side. The knife is then made to cut its way out downward, forming a flap, the apex of which is 2 mm. above the lowest point of the cornea. The cut itself is formed with the least possible sawing motion, the knife being in the first instance thrust so far forward that the section can be completed as it is withdrawn; and at the last moment the upper lid is suffered to fall. Next, the capsule is carefully opened. "For the third act of the operation," says Liebreich, "we lay the Daviel spoon gently against the lower edge of the cornea; while the left forefinger, by which the upper lid is raised, exercises a slight pressure through the lid against the upper part of the cornea. The lens is thus slightly tilted, its lower edge presses against the posterior surface of the iris, folds it forward, glides over it to the edge of the pupil, overcomes the resistance of the sphincter, and engages itself in the wound, which contact with the Daviel spoon has already caused to open. The forefinger of the left hand slightly presses the upper lid from above downward over the cornea, and thus completes the expulsion of the lens. A similar manœuvre with the lid is again employed to extrude the cortical substance which has been left behind, after a little rubbing has been done to drive it from behind the iris toward the centre of the pupil. If, after this is completed, the pupil does not appear round but seems drawn toward the wound, its natural shape may be restored by rubbing upward with the lower lid. If this does not prove effective the Daviel spoon may be introduced." [14]

This operation commends itself by its simplicity, by the small number of instruments which its execution requires, and by its comparatively slight interference with the eye. No extended statistics of its results are accessible. The dangers attending it are obvious—the possibility of the iris healing in the wound, and the production of astigmatism due to the position of the corneal cut.

Lebrun's operation much resembles that of Liebreich. The points of puncture and counter-puncture are, however, at the edge of the cornea, 1 mm. below its horizontal diameter, while the cut is made upward, its apex reaching a point at the junction of the upper and middle third of the vertical corneal meridian. During the cutting process the edge of the knife is gradually made to change its direction; starting from an angle of thirty degrees with the basis of the cornea it ends at right angles to it. At the middle of the curve, therefore, the cornea is divided vertically (Arlt). The same objection may be made to this operation that was advanced against Liebreich's, though its application here is even more forcible. The danger of anterior synechia is greater, that of astigmatism is imminent, and corneal opacity, from imperfect or delayed healing of the wound, extremely likely to occur. In the opinion of the writer, and in view of the results that a careful collection of statistics has proved to attend the method of peripheric linear extraction, the operation of Lebrun is not to be advised at the present day.

Flap Extraction.—No article on cataract would be complete without a description of this method, which for so many years stood at the head of all operations for senile cataract, and whose complete eclipse by the method of von Graefe and by simple extraction is due to their increased percentage of success. The instances in which its performance at the present day might be desirable are so exceptional that it is mainly of interest from an historical point of view. The rapidity with which it has been thrust into the background is illustrated by the fact that, within the memory of the older generation of ophthalmic surgeons now on the stage, it was the only recognized operation for senile cataract.

It is not advisable to perform this operation without an assistant. Although the spring speculum may be used to separate the lids, the finger is far preferable, both on account of the ready closure which its withdrawal permits, and also owing to the diminished danger of pressure on the eyeball. The patient being in a recumbent position, the operator sits on the edge of the bed in front of him, generally on his right side. The left hand is employed for operating on the right eye, the right on the left. The knife used is shown in Fig. 1164. If we assume that the left eye is to be operated on, the assistant takes his stand behind the patient's head. He draws down the lower lid with his right forefinger, being careful not to evert it, and spreads his remaining fingers in such a way that they may interfere with the movements of the operator as little as possible. With the forefinger of the left hand he raises the upper lid, drawing it gently upward, parallel with, but not away from, the eyeball, pressure being made against the edge of the orbit. The operator fixes the eyeball, below the cornea, with the ordinary fixation forceps. Holding the knife with its edge downward, he introduces the point in the horizontal meridian of the cornea, just at its transparent edge, and having penetrated into the anterior chamber, carries the blade rapidly across it, keeping it parallel with the iris, until it emerges on the opposite side at a point corresponding to that at which it entered. The eyeball, being now held on the knife, is thus perfectly controlled, and the fixation forceps may be dispensed with. The handle of the knife is now slightly thrown back toward the temple, and the blade pushed gently but steadily forward, completing the cut, if possible, without withdrawing the blade at all backward; great care being taken to inflict no unnecessary violence on the cornea by pulling or twisting. As the cut is completed the assistant allows the upper lid to escape from his finger and gently descend. The peculiar wedge shape of the knife used thus gives us a semicircular cut, extending around the entire periphery of the lower half of the cornea, the length of the wound being about 9 mm. and its capacity of opening in the vicinity of 4 mm., thus affording ample space for the passage of the largest cataracts.

Great care must be taken not to draw back the knife before the counter-puncture has been made, and if possible before the completion of the cut; and the hand of the operator must be perfectly steady, in order to keep the blade always in the same plane. A neglect of either of these precautions might result in the premature escape of the aqueous humor and the folding of the iris over the edge of the knife. Should this latter accident happen, gentle pressure against the cornea with the middle finger will often cause the iris to recede. If it is impossible to effect this, the cut must be completed without regard to the slight deformity to the pupil that would result from the excision of a small piece of the iris substance.

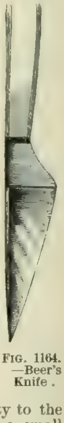

FIG. 1164.—Beer's Knife.

The cut just described can also be made upward with equally good result. This course offers no special advantages; and the execution in this direction is, in many cases, somewhat more difficult.

The operator now himself assumes the raising of the upper lid, using for that purpose the thumb of the right hand. Directing the patient to look down, he lifts up the flap with the back of the cystitome, which is so held that its cutting edge looks downward, and whose shaft now occupies the anterior chamber, while its point remains external to the eyeball, projecting inward from the inner corneal edge. Drawing the instrument, in this position, from left to right, he causes its point to glide into the anterior chamber. Once opposite the face of the lens, he makes a half-revolution by slightly twirling the handle between the thumb and fingers until the cutting edge is in contact with the anterior capsule. The knife being rapidly drawn along its face a horizontal opening is made. Another opening should be made at right angles to the first, the point of the cystitome having first been disengaged from the lens substance and passed upward to the spot at which the incision is to commence. The instrument is then laid over on its back and withdrawn from the eye, the process by which it entered being simply reversed.

To effect the delivery of the lens the patient is directed to look up. The surgeon raises the upper lid with the thumb of one hand, while he places the forefinger of the other on the lower lid. Gentle pressure on the eye, made with the thumb through the upper lid, causes the lens to turn on its horizontal axis and its lower edge to enter the wound. By now making the upper lid descend over the cornea in a succession of sweeping movements, the lens is, as it were, coaxed out and escapes from the eye. After its greatest diameter has once entered the wound, the rest passes with very little persuasion. If it was already dislocated into the anterior chamber, it will escape as soon as the cut is completed. After the removal of the lens the patient is allowed to take a brief rest. The eye must then be carefully inspected to see whether the pupil is free from cortical remains, whether the iris is well in place, and whether the edges of the wound are in proper apposition. Much information as to the state of the pupil may be gained by ascertaining whether fingers can be counted a short distance off. If there is a prolapse of the iris, it may often be made to recede by slightly rubbing the upper lid against the cornea; but if this cannot be effected it must be excised.

The after-treatment of flap extraction is similar to that already described under the head of Peripheric Linear Extraction, the dressings being identical. Less freedom, however, can be allowed the patient immediately after the operation, as sudden movements must be carefully guarded against, and the presence of a cough might be extremely prejudicial. In brief, the proper healing of the wound largely depends on the preservation of perfect quiet, on the part of the patient, during the first twenty-four hours. Occasional change, for a few minutes, from a recumbent to a sitting posture may be allowed. For several days the food should be liquid, or at least quite soft, and all chewing is to be avoided.

Some very few cases still remain in which flap extraction might with justice be preferred. Besides being applicable to dislocations of the lens into the anterior chamber, it is especially available when a foreign body is situated in the lens and requires to be extracted with it; also when a cicatricial condition of the upper part of the cornea prevents peripheric linear extraction in this region.

The description of a single remaining operation, wholly given up to-day in civilized communities, on account of the dangers to which it exposes the eye, but still in general use among the natives of India, will also be of interest in an historical point of view.

Reclination.—This is the oldest method known, and is referred to by both Galen and Celsus. It consists, in brief, in the removal of the opaque lens from the axis of vision by pressing it downward, or downward and backward, with a suitably shaped needle, introduced for this purpose sometimes through the cornea, but more generally through the sclerotic.

According to Arlt, the operation would be performed in the following manner: The pupil is artificially dilated. The lids being separated by a spring speculum, and the eyeball seized with the fixation forceps, the needle (Fig. 1165), with its convexity directed upward, is made to penetrate the sclerotic somewhat below the horizontal meridian, and about 4 mm. from the corneal edge. One cutting edge of the needle is directed toward the anterior, the other toward the posterior pole, and the point toward the middle of the vitreous humor. "After it has passed in up to its neck, the handle is turned on its axis (toward the thumb), so that the convexity, formerly upward, is now directed forward. The handle is now lowered toward the lobe of the ear, in order that the point may be pushed forward toward the edge of the lens, and farther, until it enters the posterior chamber. Steadily pushed forward, the needle now enters the pupil, where its metallic sheen is recognized, provided it emerges external to the capsule. When the point has once reached the opposite pupillary edge and passed behind it, the instrument is to be regarded as a lever, the fulcrum being situated in the sclerotic. The handle is now raised toward the nasal eminence, and the lens depressed downward and outward. The handle is to be raised no higher than is sufficient to form an angle of about one hundred and twenty degrees with the corneal basis. A brief pause with the needle in this position is necessary in order that the vitreous may settle down properly around the lens. The instrument, held thus, is withdrawn up to its neck, and then returned to the position which it occupied before its advance toward the edge of the lens. If a single performance of the manœuvre results in the lens remaining fixed, a thing usual when the consistency of the vitreous humor is normal (always provided the lens has been attacked at its centre of gravity), the handle is to be twirled round in the opposite direction, away from the thumb, and withdrawn from the eye in the line of the original puncture. Should the lens rise before the withdrawal of the needle, a second and third effort at replacement may be made. Further attempts would hardly accomplish the object, and might easily do harm by breaking up the structure of the vitreous."[15]

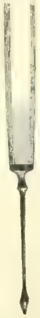

Fig. 1165.—Reclination Needle.

At the present day this operation for cataract is probably more largely performed in India than in any other part of the world. The armamentarium of the native travelling oculist consists of a sharp knife, the blade of which is wound around with some material so as to leave only the point free, and a copper probe or spatula. With the former an incision is made through the sclerotic, while the latter is introduced through this opening and the lens depressed. The inability of these self-educated practitioners to do extraction is, of course, one reason why this method is so generally used. But, in addition to this, we are told that suppurative keratitis is exceedingly frequent among the poor, rice-fed Hindoos after flap extraction. Thirty per cent. of the operations formerly performed in Calcutta are said to have failed in this way.[16] The writer here quoted also states that hardly a week passes that he does not see, in the hospitals of Calcutta, patients on whom reclination has been done, suffering from either inflammation of the choroid or from retino-choroiditis.

When reclination is followed by success, the lens probably becomes encapsuled in its new position. If, on the other hand, inflammation follows, it ordinarily involves the iris, choroid, or ciliary body, or may attack all three. The outcome is, of course, most serious. Secondary glaucoma may follow. But the lens, even when encapsuled, may subsequently act as a foreign body. For it is to be remembered that the complete absorption of a hard cataract in this position is not to be reckoned on. Destructive inflammation may come on years later and all vision be destroyed. Sympathetic inflammationn of the other eye may even ensue. It is, therefore, hardly possible to conceive of circumstances in which the operation of reclination may at the present day be regarded as justifiable.

History of Extraction.—It is uncertain whether the ancients were acquainted with this method; it is probable however, that they were, as passages in Galen and Pliny have been thought to refer to the removal of the cataract from the eye. At all events, if known, it fell into nearly complete disuse and oblivion; and not until the time of Daviel, in 1750, did it begin to be cultivated as a recognized procedure. This surgeon used numerous instruments, consisting of narrow sharp and blunt knives, and scissors; he made at first a small opening in the cornea, enlarged it afterward, and then removed the lens. His followers sought to improve his method by simplifying its application, and soon superseded the various instruments he had used by a single knife. This was subsequently modified, especially by Beer, to whom we owe the form of knife used in flap extraction at the present day. Gradually more exact rules were laid down for the performance of this operation; the situation and size of the cut, the best method of opening the capsule and pressing out the lens were all perfected. Despite the utmost care, however, used in carrying out the various steps of the operation and in the after-treatment of the patient, there was an appreciable percentage of loss; owing largely to one of three causes—diffuse suppuration of the corneal flap, defined suppuration of the same, and iritis. To diminish the danger of the second of these, but more particularly to guard against the last, Mooren proposed, in 1862, that a preliminary iridectomy be performed some two weeks before the extraction. The results which he obtained by pursuing this method were proved to be incontestably superior to those that had followed the simple operation. This was the first great step forward in the path now pursued. It allowed the lens to emerge more readily, and subjected the iris to less danger from pressure and bruising in the process. In 1863 Jakobson proposed the following operation: He narcotized his patient and made a lower section in the sclero-corneal junction, practising a broad iridectomy downward after the removal of the lens. He thus gained the advantage of doing the whole operation at one time, but incurred the disturbing effect of an iridectomy downward. Previous to the bringing forward of either of these methods, Schuft (now Waldau) had invented, and in 1860 published, a series of spoons intended to remove the lens through a small wound at the edge of the cornea. These were, however, large and clumsy, did great violence to the eye, and were, in 1865, superseded by others much more delicate, invented by Bowman and Critchett. Outspooning remained for a time a favorite method in England, but was afterward given up on account of the dangers which it involved. In 1865 von Graefe brought out the method that bears his name, and gave an account of it to the Heidelberg Society at its annual meeting. It quickly found its way into general favor, and, with the modification in the cut described in the course of this article, has remained the popular method up to the present day.

Other modern procedures demand a brief notice. In 1866 Alexander Pagenstecher described an operation for removing the lens in its capsule through a broad incision made with a lance knife, and by means of an iridectomy downward and outward. A specially constructed scoop was employed. In 1867 Weber devised a lance-knife, 12 mm. broad and somewhat concave on its back. With this he entered the anterior chamber at the lower or lower-inner edge of the cornea, in the plane of its basis, and made a wound 10 mm. in length. If he thought it best to remove any iris, he excised but a small piece, and that from the pupillary edge. The opening of the capsule and removal of the lens, which latter was effected by pressure, completed the operation. Kuechler, in 1868, proposed to remove the lens through the natural pupil, making an incision straight across the cornea in its horizontal meridian. Analogous to this are the operations of Liebreich and Lebrun, already described.

A consideration of the following figures will show why flap extraction has fallen into disuse, and why the peripheric linear method has taken its place.

Graefe's own statistics were as follows: Simple flap extractions, 600—loss, 7 per cent.; flap extractions with iridectomy, 900—loss, 5 per cent.; linear extractions, 600—loss, 2.8 per cent. Horner gives: Linear extractions, 1,088—loss, 2.67 per cent. Noyes has collected from various sources: Flap extractions, 10,094—loss, 10.4 per cent.; linear extractions, 10,661—loss, 5.8 per cent.

The larger proportion of loss given, according to the figures of Dr. Noyes, would naturally be connected with the large number and varying skill of the surgeons whose results are thus grouped. *Hasket Derby.*

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[5] O. Becker: Graefe-Saemisch, vol. v., p. 256.

[6] *Loc. cit.*, p. 259.

[7] Becker: Graefe-Saemisch, vol. v., pp. 178, 179.

[8] Traité théorique et pratique des maladies des yeux, t. ii., p. 171.

[9] Graefe-Saemisch, vol. iii., p. 263.

[10] Archiv für Ophthal., 30, ii., S. 266.

[11] Wecker: Thérapeutique oculaire, p. 466.

[12] Graefe-Saemisch, vol. iii., p. 295.

[13] Graefe-Saemisch, vol. v., pp. 341, 342.

[14] Eine neue Methode der Cataract-Extraction, pp. 12, 13, 14, Berlin, 1872.

[15] Graefe-Saemisch, vol. iii., p. 254.

[16] Macnamara: Diseases of the Eye, p. 525.

[17] Archiv für Ophthalmologie, Jahrg. 30, Abth. 2.

CATARRH, NASAL. See *Nasal Cavities, etc.*

CATECHU.—Cutch; Black Catechu. "An extract prepared from the wood of *Acacia Catechu* (L.f.) Willd. (fam. *Leguminosæ*)" (U. S. P.). Catechu is similarly obtained from the wood of *A. Suma* Kurz. That of the present edition of the British Pharmacopœia is discussed under *Gambir*. This species of acacia is a crooked, straggling tree of thirty to forty feet in height, with a trunk about a foot in diameter. It grows commonly in India and Burmah, and yields a very durable, hard timber and a tan bark. The sap wood is whitish, the heart wood of a very dark brown. It is said that both are extracted for the catechu, the process being by boiling the chips. The decoction, more or less purified by straining, is evaporated by artificial heat and is then moulded into various forms. The moulds are commonly lined with leaves, the remains of which adhere to the outer surface of the dried masses. The latter are of various forms and sizes, according to the custom of the locality or the convenience of the maker. The best usually come in the form of slabs or blocks, of the size and form of an ordinary bread pan. In India a superior quality, of a light brown color, is prepared chiefly for mastication by introducing sticks into the thickened decoction, when the catechu collects upon them, after the form of crystals. Dymoch and Hooper ("Pharmacographia Indica," i., 558) describe a very high-priced sort which is collected from cavities in the trunk. This is called *Khersal* or *Khairsal*, and is of a very pale-brown or yellow color. The official description of catechu is as follows:

In irregular masses, containing fragments of leaves, dark brown, brittle, somewhat porous and glossy, when freshly broken. It is nearly inodorous and has a strongly astringent and sweetish taste.

If 20 parts of catechu be digested with 200 parts of alcohol and the liquid filtered, the undissolved matter, after being dried at 100° C. (212° F.), should not exceed 3 parts in weight.

The tincture, diluted with 100 parts of water, acquires a green color on the addition of ferric chloride T.S.

If 2 parts of catechu be boiled with 20 parts of water, a brownish-red, turbid liquid will be obtained which turns blue litmus paper red.

Upon incineration, catechu should not leave more than six per cent. of ash.

To this description it may be added that the color of some which is very good may be better characterized as a brown-black, and that a microscopical examination reveals the presence of a large quantity of minute crystals of catechin. Emphasis should be laid upon the fact that good catechu is nearly odorless. Much of what comes to our market possesses a vile odor. It is toughish, scarcely porous, and has a waxy or greasy looking surface instead of the lively, slightly sparkling lustre of that which is pure. Such is largely used for tanning and similar purposes, but is not fit for medicinal use.

About one-third of catechu consists of *catechin* ($C_{21}H_{20}O_9 + 5H_2O$), and about one-half of *catechu-tannic acid* ($C_{21}H_{18}O_8$). The latter can be obtained from catechin by heating, especially with the addition of water or alkalies.

Catechu, as its composition would indicate, is a pure astringent, which may be generally used either externally or internally, when this effect is desired. We have official a compound tincture, of ten-per-cent. strength, with diluted alcohol and one-half per cent. of cassia, the dose 2 to 8 c.c. (fl. ʒ ss. to ij.). The official troches contain each 6 cgm. (about gr. i.) of catechu, with tragacanth and sugar. *Henry H. Rusby.*

CATHARTICS. See *Laxatives* and *Purgatives.*

CATHETERISM OF THE URETHRA.—The term catheterism, often erroneously written catheterization, is employed to designate the various methods used in exploring and relieving the many pathological conditions of the urethra and bladder. The term is especially used to designate the introduction of hollow instruments through the urethra into the bladder for the purposes of withdrawing the urine, evacuating blood clots, removing fragments of stone after litholapaxy, exploring, irrigating the urethra and bladder; and the employment of solid instruments for the purposes of dilating stricture, of removing foreign bodies, and of crushing stone.

The word catheter, derived from the Greek *καθίημι*, meaning a "thing to send down," or "to let into," conveys no idea of the character of the instrument or of its use, nor whether it is solid or hollow, straight or curved, conical or cylindrical, large or small. But the derivation of the word may serve to explain why the term catheterism is employed to indicate the introduction of all varieties of urethral instruments for whatever purpose employed.

Throughout this article the term catheterism will be confined in its meaning to the introduction of hollow instruments into the bladder, through the urethra, for the purposes of evacuating the urine; of examining the urethra and interior surface of the bladder; of introducing various medicaments for the relief of pain or for the cure of diseases; of irrigating the urethra and bladder; of distending the last-named organ with either water or air as a preliminary to operative interference, and of establishing continuous drainage in cases of cystitis after injuries or operations upon the urethra, prostate gland, or bladder.

A catheter is a hollow instrument either open at both ends or terminating at one end in a solid point with an opening placed laterally or on the superior aspect of the instrument; this opening is known as "the eye." Catheters vary in size from 2 to 30 mm. in circumference, and from thirteen to fifteen inches in length. They are either flexible or rigid, straight or curved, cylindrical or conical. If the instrument is cylindrical, a uniform calibre is maintained throughout its entire length; if it is conical, it tapers toward the vesical end and terminates either in a fine point or in an olivary tip, becoming smaller in diameter as the end of the instrument is reached.

The exact method of manufacturing the best grades of flexible catheter is a secret with the individuals by whom the instruments are made; especially is this true of the preparations employed for coating, as well as of the method of giving the high polish and satin finish which the better grades of instruments possess.

Soft rubber, bevelled-eye catheters, the so-called "soft caoutchouc catheters," are made from india rubber which has been vulcanized. There is also a more rigid form, the cheaper grades of which are manufactured from either cotton or linen; these materials are employed as a framework, and are coated with either shellac or resin varnish.

The objection to the cheaper forms of flexible catheter is the readiness with which they absorb water, making them liable to swell, as a result of which the coats crack and peel, the elasticity disappears, and the instrument is rendered stiff, brittle, and worthless. The use of antiseptic solutions causes the instrument to become rough on its surface and so brittle as easily to be broken.

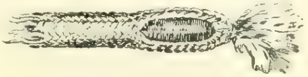
FIG. 1166.—Woven Eye of Catheter.

The most expensive and reliable flexible catheters are made from either cotton, or Lisle, or silk thread woven into a web and usually coated with a gummy material. As soon as this material becomes dry it forms a translucent cover, takes on a high polish, and at the same time remains elastic and pliable. When properly coated the instrument should be able to withstand moist heat, steam, dry heat, or immersion in boiling water for at least five minutes, and should have the power to resist the action of ordinary antiseptic solutions, acid or alkaline urine, and pus. The frame should be perfectly smooth and free from irregularities, the end should be firmly stayed, and the whole instrument should possess the highest tensile strength.

Interesting statistics are given by Gouley in an article on catheterism which appeared in the New York *Medical Journal*, November 4th, 1899, in which he says: "The tensile strength of different qualities of web catheters was ascertained to be as follows: That of an English commercial catheter was 42 pounds; that of an American commercial catheter 54 pounds; that of an American Lisle thread catheter 56 pounds; that of an American silken linen catheter 60 pounds, and that of an English silk web catheter 85 pounds. An American silk web catheter of the best quality was then tested to 115 pounds without breaking, but the varnish was stripped off at each end."

Theoretically these instruments are supposed to be as highly polished on the inside as on the outside, so that they may be more readily cleansed and sterilized, and the danger of infection thereby lessened. Unfortunately, it is wellnigh impossible to arrive at this condition of perfection. The nearest approach is to be found in the high grade of catheter, but at a greatly increased cost. The eye of all flexible web catheters should be woven, strengthened, and stayed, whereby the continuity of the frame is left unimpaired. In the inferior grade of web catheters the eye is formed by cutting with a punch, which is most objectionable, as the catheter is very apt to fracture at that point.

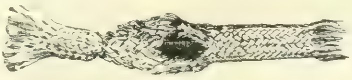
FIG. 1167.—Eye Cut with a Punch.

Flexible catheters made of silk web are by far the most serviceable and the best. They cost more than those made from other materials, but are cheaper in the end; for they are more durable, and, with proper care, can be made to last a long time. They are not so liable to crack or break as are the cheaper varieties; they are more easily sterilized, and hence are the safest of all the varieties of web instruments that can be employed. The danger of infection from their use is lessened. They do not become sticky, nor do they blister in warm weather;

they are not injured by contact with antiseptic solutions, tissue fluids, or the fatty materials with which they are anointed before use.

In the shops is found a hard-rubber gum elastic catheter which is sold under the name of "the English catheter." This instrument is very durable and is coated with a material which is highly polished; the shaft is re-enforced by a steel stilette. On being subjected to heat the instrument becomes soft and pliable and may be made to assume an exaggerated curve, which being maintained by the stilette, will become permanent on cooling. This form of catheter may be bent to assume the prostatic curve; it is then passed into the urethra, as far as the membranous portion, when on gently removing the stilette the curve will become greatly expanded and will oftentimes pass over an enormously enlarged middle lobe of the prostrate gland when all other forms of catheters have failed. Gross states that in some cases it is of advantage "to bend back the shaft of the instrument so that it will resemble somewhat an italic *S* procumbent." Catheters of this description may be kept on an over-curved stilette, by which means the increased prostatic curve, desired in some cases of prostatic hypertrophy, is maintained, the instrument being always ready for use in case of an emergency. The sphere of usefulness of the English gum catheter is limited; in some conditions of prostatic hypertrophy it is invaluable.

The india-rubber or soft vulcanized caoutchouc catheter, the most improved form of which is manufactured in the United States, is sold under the name of "Nélaton," or "Jacques catheter," so-called after its original Parisian maker. Many cheap and poor varieties of this instrument are sold. If an inferior quality of catheter is employed, it will be found that after having been used for a short period the instrument has become swollen, soft, and flexible, and has increased in calibre as well as in length, so that its further use is impossible. Should the rubber contain an excess of vulcanizing material it soon becomes hard and brittle, and when catheterism is attempted the instrument may break and a portion be left in either the urethra or the bladder. In warm weather catheters are liable to become hard and brittle, notwithstanding the care expended on their preservation. They are injuriously acted on by fatty acids and by the materials employed as lubricants. They withstand boiling but poorly, and are soon rendered useless by the action of the materials applied to sterilize them.

"The eye" is often badly constructed and is generally situated too far from the vesical end. The lumen is usually too large, rendering the end of the catheter overflexible, so that its passage through the urethra is accomplished with difficulty; at the same time such an instrument is liable to double on itself, thereby injuring the urethra. The site at which "the eye" is located is in danger of being fractured. Another objection is that the instrument from the eye to the tip is hollow, whereas it should be solid so as to prevent the accumulation of foreign material, such as pus, blood, and microbes. When hollow it is very difficult to cleanse, and wellnigh impossible to sterilize. In practice many cases are met with in which the use of an inferior variety of soft-rubber catheter has given rise to much trouble. In one instance, where the patient was practising auto-catheterism, the end of the instrument broke off, and was left in the bladder; owing to a hypertrophic condition of the prostate gland a perineal section was rendered necessary to remove the fragment. In another case part of the instrument was broken off in the urethra and was then forced into the bladder by the attendant in his efforts at removal; it was extracted by means of a lithotrite.

Recently there has been put upon the market a new form of soft-rubber catheter which—so it is claimed—combines the qualities of the pliable soft-rubber catheter with the elastic spring of the firm, flexible instrument. This is accomplished by having the anterior portion pliant and the posterior more rigid. By this device it is presumed that the pliant portion will apply itself to the curves of the urethra, while the firmness of the posterior part will permit the operator readily to pass the instrument through an irritable, spasmodic urethra or through an obstructing lobe of the prostate gland into the bladder. The vesical end of the instrument terminates in either a cylindrical or an olivary tip. This form of catheter is still on trial.

The soft-rubber catheter is probably the one in most general use. It easily adjusts itself to the shape of the urethra; it is not liable to exert an injurious pressure on the canal, and there is no danger of producing a false passage. A properly constructed soft-rubber catheter should be at least thirteen inches long, should vary in circumference from 10 to 30 mm., and should be perfectly pliable and highly polished. The eye should be a little less than one-quarter inch (5 mm.) from the vesical end, and its diameter should be the same as that of the lumen of the instrument. Usually the eye is placed laterally, but recently an improved form of soft-rubber catheter has been manufactured in which the lateral eye is omitted; the tip of the vesical end is left well rounded and open. In my experience this modification has proved most satisfactory. When the eye is placed laterally, the tip of the catheter, from the eye to the vesical end, should be solid, and not hollow, for reasons already given. The termination of the instrument may be either conical or cylindrical. The proximal end should be conical in shape and of a larger calibre than the shaft, so that the nozzle of the irrigating apparatus can be easily attached when required.

The soft-rubber catheter is especially designed for evacuating the urine; for irrigating the urethra and bladder with various medicated solutions; for introducing anæsthetic remedies for the production of local anæsthesia; for distending the bladder with either water or air, when it is proposed to perform suprapubic cystotomy or Bottini's operation on the prostate gland; for supplying continuous drainage for the relief of chronic cystitis and inflammatory diseases of the prostate gland, and for preventing urethral fever after operations on the urethra. It is sometimes employed as a means whereby to measure the increase in length of the urethra in cases of prostatic hypertrophy. It should be used, wherever possible, in preference to any other form of catheter. Its introduction gives rise to but little pain except in those cases in which the urethra is very sensitive and spasmodic; then a more flexible instrument, such as the silk web catheter, will pass with greater ease and with less pain. In cases in which it is found difficult to pass the catheter, owing to urethral spasm, its firmness may be re-enforced by the introduction of either a filiform bougie or a wire stilette, which should extend to within a quarter of an inch of the eye of the instrument and should be removed as soon as the compressor urethræ muscles are passed. The finest grade of soft-rubber catheter is not only very durable, but is more readily sterilized than any other grade of flexible instrument. It can be boiled for the space of five minutes without injury. It is always the instrument to be chosen for self-catheterism, wherever possible. Not only is its use attended with less pain, but it is almost impossible for the patient, unless the urethra and prostate gland be very much inflamed or congested, to injure himself, no matter how roughly it may be used.

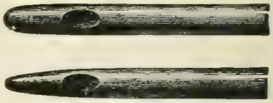

FIG. 1168.—Tips of Soft-Rubber Catheter.

The soft, pliable instrument is to be selected, if possible, when the establishment of continuous drainage is required. Occasionally it will be found necessary, owing to the condition of the urethra or the prostate gland, to make use of a flexible web or even a metal catheter. Continuous drainage by use of the latter instrument is always attended with more or less pain and danger of an abscess forming at the peno-scrotal junction. When it becomes necessary to leave a metal instrument in the urethra the patient should be carefully watched.

Five years ago the writer read before the Philadelphia Academy of Surgery a paper in which he strongly advocated continuous drainage after injuries of, or after operations upon, the urethra, prostate gland, or bladder; and also in chronic inflammatory diseases of these organs, especially when associated with alkaline urine, pain, tenesmus, and frequency of micturition, and with chronic urethral fever. The ideas put forth were based upon large experience. The subject elicited a heated discussion, every member of the society who was in attendance taking exception to the method of treatment suggested. A radical change in the views of the profession on this subject has since taken place, doubtless owing to the investigations and writings of Guyon and Michan, who have strongly advocated in suitable cases the mode of treatment here described, and who fully verified all that was claimed for the benefit to be derived from this method; since which time its employment has become general. This treatment is to be followed in cases of chronic cystitis, especially when there is frequency of urination; in cases of pain attended with an ammoniacal urine which is loaded with pus; and also in cases in which the inflammation of the bladder depends on obstructive enlargement of the prostate gland. When retention of urine is due to the last-named cause, and a flexible catheter has been successfully passed, it should be allowed to remain in the urethra for at least four days. If the instrument is removed immediately after the urine has been evacuated, in a few hours catheterism will again become necessary, and, as is frequently the case, it will be found impossible to reinsert the instrument; thus making either aspiration or some more radical operation necessary, which would have been avoided if the catheter had been allowed to remain *in situ.* When the catheter is permitted to remain in the urethra, a beneficial effect of continuous pressure on the inflamed and congested canal is produced, the tenesmus is relieved, and the bladder is put at rest. When the instrument is allowed to remain in the urethra for the period indicated, it will be found that on its removal not only can a much larger instrument be easily inserted, but usually no further difficulty from urination will be experienced. This method of draining the bladder is also indicated in wounds of, or after plastic operations upon, the urethra, and with proper care the catheter may be allowed to remain *in situ* for a week, or longer if necessary.

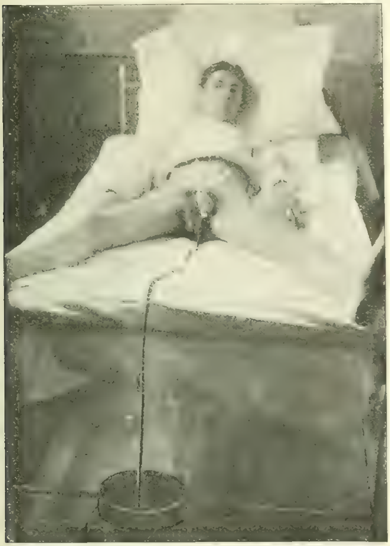

FIG. 1169.—Continuous Catheterism, in the Recumbent Posture. (Horwitz.)

In over one hundred and fifty-eight cases of external perineal urethrotomy which have been performed by the writer, and in which the soft-rubber catheter was allowed to remain in the urethra until the new canal had entirely formed around it, in not a single instance did a perineal fistula follow, as is so commonly the result in the old method of treatment. Whenever it was possible the wound was closed by means of interrupted sutures, union taking place by first intention, and the patient being thus saved several weeks of tedious convalescence.

In cases in which internal and external urethrotomy combined has been performed, and it is then found to be difficult to pass a catheter in the usual manner, on account of the rough and nodular condition of the urethra, the act can be readily accomplished by inserting a long pair of forceps, designed for the purpose of removing foreign bodies from the urethra through the meatus, and making the jaws of the instrument appear at the perineal wound. The proximal end of the catheter is then caught and drawn from behind forward until it protrudes an inch or so beyond the meatus. The vesical end is then passed along a steel gorget, through the membranous and prostatic portions of the urethra, into the bladder. In cases of hæmaturia in which the bleeding is due either to a vesical growth or to some pathological condition of the prostate gland, continuous drainage is invaluable. In chronic cystitis associated with alkaline urine, polyuria, and frequency in passing water, especially if due to prostatic

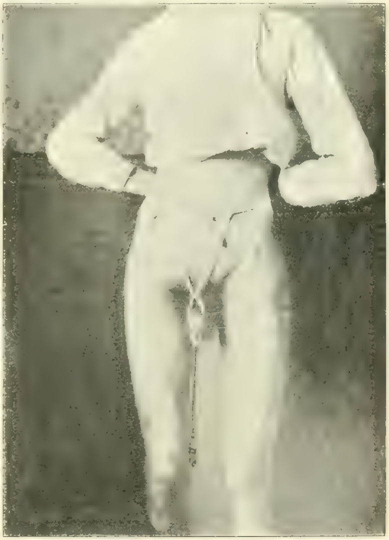

FIG. 1170.—Intermittent Drainage; Continuous Catheterism. (Horwitz.)

hypertrophy, or when attempting to get the patient in proper condition for a capital operation on the urethra, prostate gland, or bladder, continuous drainage is always indicated as the preferable method of treatment. In a few instances it will be found that the presence of a catheter in the urethra will give rise to urethritis. This is especially true if the instrument has been previously sterilized with formalin and not thoroughly washed before its introduction. This condition, however, is harmless; it usually requires no treatment, and, as a rule, promptly disappears on removal of the instrument. When continuous drainage is employed there is always danger of an abscess forming at the peno-scrotal junction, the result of pressure whilst the penis is in the pendant position. This complication is not liable to follow the use of a soft-rubber catheter, but may ensue when either a flexible or a metal instrument is employed; the latter being most liable to give rise to the trouble. If the surgeon, on the alert for this danger, watches the peno-scrotal junction for any suspicious redness, tenderness, or œdema (forerunners of an abscess and urinary fistula), the threatened condition can be averted by the prompt removal of the catheter.

Singular as it may seem, the presence of a catheter placed permanently in the urethra, far from producing pain, is usually followed by relief, by assuaging strangury and by putting the bladder at rest and permitting the patient to secure much-required sleep. For a few hours after the introduction of the catheter a feeling of weight in the perineum is usually complained of, but this soon subsides.

Many methods have been suggested to insure the retention of the catheter within the canal and prevent its slipping from the urethra. After making trial of the various modes that have been devised, the writer has fixed upon the following as the most practicable: The patient is placed in bed; the catheter is inserted, and connected with a drainage tube, which conducts the urine into a vessel at the foot of the bed. The instrument is kept in place by means of a piece of tape, tied so that the knot is located on the under surface of the catheter. The two ends of the tape are carried to the middle of the body of the penis and then knotted once more; the ends are carried around the organ and another knot is tied on the dorsum of the penis; the extremities are then carried up and fastened to a band around the waist. The manner of securing the instrument is probably more clearly delineated in the accompanying figure (Fig. 1171.)

If a soft-rubber catheter cannot be employed a good flexible web instrument should be used. The objection to these instruments is that their continued presence gives rise to irritation, and they are consequently not so well borne by the patient; the utensil in a short time becomes blistered, cracked, and worthless, especially if the urine be alkaline and contain an excess of phosphates. It is always well, no matter what variety of catheter is employed, to change it at least every third day. The urethra and bladder should be irrigated daily with a normal saline or warm boric-acid solution. Care should be taken to prevent the eye of the catheter, which is just within the vesical sphincter, from becoming plugged with blood or pus.

Various self-retaining catheters have been devised by surgeons, but they have not generally met with the approval of the profession. They are usually unmanageable, hard to introduce, frequently give rise to hemorrhage, and are difficult to sterilize. They possess no advantage over the method of retaining the catheter suggested by the writer. Their employment is not recommended. An instrument of this description devised by Petzzer consists of a soft-rubber catheter the vesical end of which is made to project laterally well beyond the shaft of the instrument. This projecting portion, when stretched over a metal carrier, becomes obliterated. After the catheter has been introduced the stilette is removed, when the projection reappears and is held in place by coming in contact with the narrow vesical neck. A simple device is that suggested by Malécot; it consists of a soft-rubber catheter, with two pliable loops at the vesical end. When this instrument is passed through the urethra the loops are pressed against the shaft of the catheter, and then, owing to their elasticity, they return to their original position as soon as the catheter enters the bladder and the pressure exerted upon them by the walls of the urethra is removed.

It is only in acute cases accompanied by fever, and after operations upon the urethra, prostate gland, and bladder, that it is necessary to keep the patient in bed whilst continuous drainage is made. In many cases of long-standing prostatic disease the writer has prolonged this method of treatment for the space of six weeks with great benefit, the patient being allowed to sit in a chair, to lie on a sofa, or to walk to a limited extent around his chamber. When it is desired to let the patient be up and about and still maintain continuous drainage, the catheter is kept in place as shown in Fig. 1171, the end of the instrument draining into a six-ounce bottle, which is suspended by tapes to the harness around the patient's waist, and which can be emptied whenever necessary.

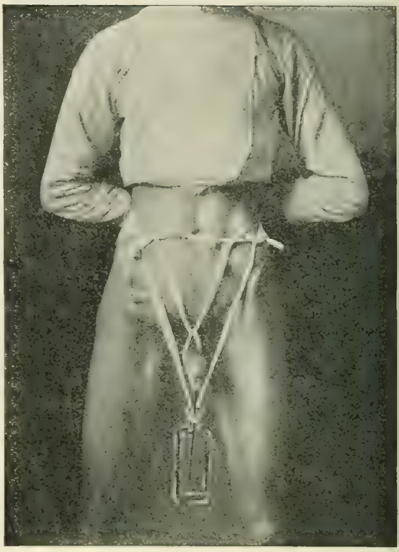

FIG. 1171.—Continuous Drainage, the Patient Being Allowed to be Up and to Walk About. (Horwitz.)

In cases of external perineal urethrotomy in which drainage is to be maintained until the perineal wound is healed, the object being to prevent the urine from passing through the wound, it will be seen by Fig. 1170 that the catheter is kept in place in the manner already described, the proximal end being closed with a plug, to be removed whenever there is a desire for urination.

Flexible web catheters should be at least thirteen inches in length and may vary in circumference from 2 to 25 mm. They should be thoroughly covered with the coating of gum employed for the purpose; the entire surface of the instrument should be perfectly smooth, highly polished, and capable of resisting heat, at a temperature of 212° F., for at least five minutes. Catheters of this description should possess firmness and elasticity, and at the same time they should be pliable, having the same degree of stability from one end to the other. They should never be rigid, especially toward the vesical end. In order to accommodate the nozzle of the irrigating apparatus the proximal end should be funnel shaped and of a larger calibre than the shaft of the instrument. Except in flexible catheters, designed for evacuating blood clots from the bladder, these instruments should possess but a single eye, which should be at a distance of rather less than a quarter of an inch from the vesical end and located laterally. The lateral eye of straight web catheters is frequently omitted, the instrument being simply a tube open at both ends. In some forms of curved catheters, the so-called "elbow catheter," it is found to be advantageous to have the eye on the superior aspect of the concavity of the point instead of being placed laterally. When catheters terminate with either an olivary tip or a long conical point, the eye must be situated about one inch from the vesical end. The eye should always be woven into the instrument, and from the eye to the vesical end the tip should be solid. The shape and curve given to the vesical end of the instrument will depend on the purpose for which the catheter is designed.

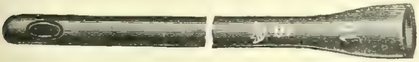

FIG. 1172.—Flexible Woven Eye Cylindrical Catheter.

Flexible catheters, being firmer and not so pliable as the soft-rubber instruments, possess the advantage of having a greater resistance along the shaft, are less apt to bend, and are more likely to pass along a urethra in which obstructions exist; besides, they are always under the control of the operator. The employment of flexible catheters is indicated in cases in which there is an irritable or spasmodic condition of the urethra, arising from either inflammation or hyperæsthesia. The instrument usually employed when these conditions exist is a flexible woven-eye cylindrical catheter, shown in Fig. 1172.

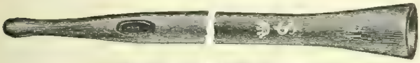

FIG. 1173.—Olivary Tip Catheter.

In cases of stricture of the urethra of large calibre a flexible catheter, varying in calibre from 5 to 15 mm., may be employed; it must be cylindrical, or must terminate in an olivary or conical tip. This form of catheter is likewise made with a sharp conical termination shaped somewhat like a rat's tail; hence it is frequently spoken of as the "rat-tail catheter." Instruments of this form are of special service in cases of retention of urine due to prostatic hypertrophy in which the obstruction results from enlargement of the lateral lobe, causing the urethra to deviate markedly to one side or the other. In such cases the long narrow projection at the vesical end readily follows the lateral curve of the prostatic portion of the canal. When the retention of urine is due to enlargement of the middle lobe it is well to employ a flexible catheter which at about one-half inch from its vesical end is bent at a slight angle, or "elbowed" as it is called, so that the tip of the catheter glides along the anterior wall of the urethra and is readily guided over the obstructing lobe of the gland, passing through the urethra into the bladder. This instrument is known as "Mercier's coudé catheter," more commonly spoken of as the "prostatic catheter."

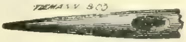

FIG. 1174.—Conical Tip (Rat-Tail) Catheter.

In order to facilitate the passage of the Mercier catheter in difficult cases, Guyon recommends that the instrument be constructed with beaks of different lengths, and that the angle formed by the junction of the beak and the shaft should be of different degrees. The angles that he suggests the catheter should have are 40, 35, 30, and 25 degrees.

Mercier's catheter is frequently employed to determine the length of the urethra in cases of senile hypertrophy. When there is marked increase in the size of the prostatic gland, with lengthening of the urethra, a modification of the elbow catheter is employed, known as "Mercier's bicoudé catheter." In this instrument there are two bends—one about half an inch from the vesical tip and a second one at a distance of a little over two inches from the first.

Guyon has devised a catheter intended for the relief of retention of urine due to prostatic obstruction. In this instrument, which is constructed somewhat on the same principle as Mercier's, the angle at the point is more acute and the instrument terminates in a conical tip, the eye being located on the superior, instead of the lateral, aspect of the catheter.

In rare instances, where there is a very unusual enlargement of the middle lobe of the prostate gland, and especially where there is marked increase in the length of the urethra, some surgeons prefer a catheter with a full semicircular curve, terminating in either a conical or an olivary point.

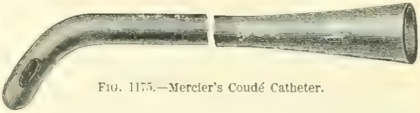

FIG. 1175.—Mercier's Coudé Catheter.

Flexible catheters are never to be employed when a soft-rubber instrument will answer the purpose. When auto-catheterism becomes necessary, as in prostatic hypertrophy, the use of the flexible instrument should be reserved until the soft-rubber catheter can no longer be employed.

Flexible double current catheters have been devised for the purpose of irrigating the bladder. They are quite rigid and possess no advantage over those made of metal. Their use is not recommended.

My experience has led me to infer that no benefit is derived from the employment of these double current instruments. There are many other varieties and forms of catheters which have been designed at different times for the relief of various conditions, but they have not met with the approbation of the profession and have but few advocates.

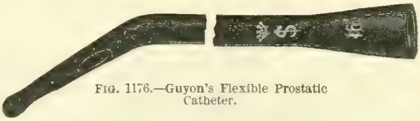

FIG. 1176.—Guyon's Flexible Prostatic Catheter.

"Evacuating catheterism" is a term used to designate the use of the instrument when rendered necessary for the discharge of purulent urine, for the expelling of residual urine retained by stricture, by prostatic hypertrophy, or by blood clots, or for the removal of detritus following the crushing of stone.

In some of these conditions the use of metal catheters is essential. But the great improvement effected in recent years in flexible instruments, which are now made of any desirable size or curve, has caused the profession generally to abandon the employment of metal instruments, except for the relief of retention of urine due to tight strictures, for the removal of blood clots or of fragments of stone after litholapaxy, and for making an endoscopic examination.

Metal catheters are made of either tin, steel, silver, or German silver, the latter being most commonly in use. These instruments should be ten inches in length, and should vary in diameter from 5 to 30 mm. They must be perfectly smooth, polished, and of light weight. Close to the vesical end, on either side of the catheter, is placed an eye for the passage of urine. The tip should be closed, rounded off, and very nearly of the same calibre as the body of the instrument. The proximal end is open and usually provided on each side with a small ring to which pieces of tape may be fastened when it is necessary to secure the catheter *in situ*. It is important that a metal catheter should have the same curve as that assumed by the more fixed portion of the normal urethra; this curve is measured from the front of the triangular ligament to the neck of the bladder. It begins in the penile urethra, about one inch and a half from the bulb, and reaches its lowest point as it passes through the anterior layer of the triangular ligament; it then passes through the membranous and prostatic portions of the canal, upward and backward, toward the bladder. The normal urethral curve will vary under different conditions. It may be a good deal straightened by lateral pressure made on either side of the root of the penis. It is lengthened when the bladder is distended with urine, or in cases of prostatic hypertrophy. The curve is more acute in children, and, according to Gross, "in adults where general development is below the average"; hence the curve of the catheter, both in adults of this type and in children generally, "should be increased, or should describe an arc of a smaller circle."

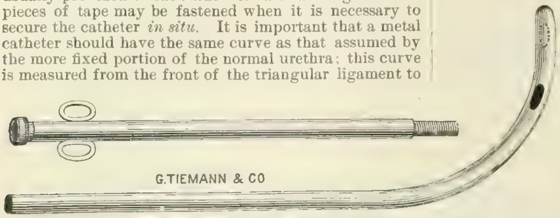

FIG. 1177.—Ordinary Metal Catheter with Thompson Curve.

Change in the curve may result from abscess, from infiltration of urine into the perineal tissues, from tumors in the vicinity of the rectum or scrotum, such as hernia, hydrocele, and hæmatocele, or from tumors of the testicle. In corpulent persons the curve of the urethra is diminished, and consequently a catheter with a segment of a larger circle is required; on the other hand, in spare men the curve is more acute. The traction exerted by the abdominal muscles on the suspensory ligament renders the curve more abrupt, and it is for this reason that when a catheter is to be passed the patient should be placed in the recumbent posture with the shoulders elevated.

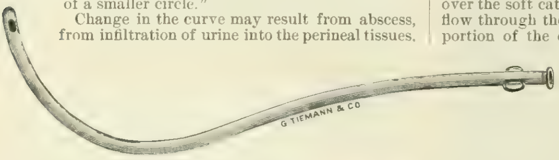

FIG. 1178.—Over-Curved Silver Prostatic Catheter.

Mr. Briggs first demonstrated that the fixed curve of the urethra is the arc of a circle three and one-quarter inches in diameter; or of a circle described by a radius one and five-eighth inches in length, the chord of the arc of which measures two and three-quarter inches. This statement was corroborated by a series of investigations made by Sir. Henry Thompson, who pointed out that the curve of the metal catheter should always be fashioned according to the rule just given; since which time instruments so constructed are spoken of as having the "Thompson curve."

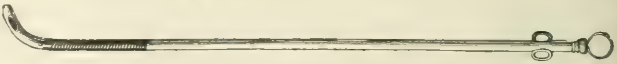

FIG. 1179.—S. W. Gross' Spiral Prostatic Catheter.

The axis of the point of the instrument should form a right angle with the axis of the shaft. The curve of the urethra can be temporarily obliterated by means of a straight instrument.

The great improvement in the manufacture of flexible catheters in the present day has caused the employment of those made of metal to be very seldom necessary. As Sir Henry Thompson has so well said: "The flexible instrument is capable of effecting all the good which can be accomplished by the metal instrument, and it does it with less pain and irritation to the patient. The difference between the two in most hands means a difference of bleeding and not bleeding, pain and very slight discomfort, freedom from subsequent irritation and an attack of chills and fever, and of course, as a sum of these differences, a safe, easy, and rapid success in place of a painful and protracted one."

The employment of the metal catheter may be advantageous when the urethra is irritable and spasmodic and when the instrument, if it is to be passed successfully, must possess a certain degree of rigidity. Its use is also indicated when the stricture is irritable, nodular, and tortuous; for the relief of retention of urine caused by blood clot; and in some cases of hypertrophy of the prostate gland. A metal instrument should not be employed for continuous drainage if it can possibly be avoided. If, however, its employment for this purpose should become necessary it should not be allowed to remain in the urethra for a longer period than four days, as its presence is liable to give rise to the formation of abscesses at the peno-scrotal junction. Flexible instruments are preferable to those made of metal when it is desired to irrigate the urethra or bladder. The double-current irrigating metal catheter is an unnecessary instrument. It possesses no advantage over the soft catheter; if the irrigating fluid is allowed to flow through the double-current instrument only a small portion of the diseased mucous membrane of the bladder is reached by the medicament. Should the outflow be checked, whereby the viscus is distended, no advantage is gained over the employment of the ordinary single tube soft-rubber catheter.

In very old men, with an inordinate enlargement of the prostate gland, especially in its longitudinal direction, an over-curved silver catheter, the so-called "prostatic catheter," is often of great service in relieving retention of urine. The instrument should be at least twelve inches in length, the curve of which should form an arc equal to one-third the circumference of a circle five and a half inches in diameter. This instrument has the high commendation of Sir Benjamin Brodie, and was rendered extremely popular in this country by the teaching of the elder Gross. Its use is restricted to exceptional cases and it should not be employed until other instruments have failed. It is very dangerous in the hands of those inexperienced in the manipulation of urethral implements. If improperly or roughly used it is very liable to lacerate the urethra or wound the prostate gland. Some genito-urinary surgeons absolutely condemn its employment; this, I am confident, is a mistake. On several occasions I have been called in consultation to attend patients suffering from retention of urine due to a prostatic hypertrophy on whom all the various forms of catheters had been unsuccessfully employed, when I was enabled to pass the over-curved prostatic catheter without injury or difficulty, hence preventing the necessity for aspirating the bladder or performing a more serious operation. The catheter should be passed with great gentleness; no force should ever be exerted; and in some instances where the beak of the instrument is prevented from entering the bladder by the enlargement of the middle lobe of the prostate gland, its onward progress may be facilitated and often successfully accomplished by inserting the index finger of the left hand, which has been well lubricated with sweet oil, into the rectum and pressing the instrument gently upward toward the pubes, whilst at the same time by means of the right hand, which holds the proximal end of the instrument, the handle should be depressed between the thighs and gently urged onward. To those who have had experience in the use of urethral instruments the prostatic catheter is of great value, but when employed by a novice it is not free from danger.

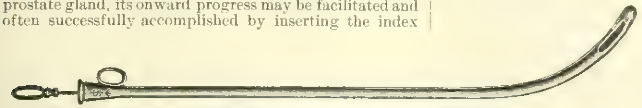

Fig. 1180. Agnew's Mucus Catheter.

The spiral silver catheter with a Mercier coudé curve was devised by the late S. W. Gross. It is but seldom employed in civil practice, well-made flexible instruments being more serviceable. In the equipment of surgical cases for the army and navy this form of catheter is invaluable, being readily sterilized, durable, and not affected by climatic changes.

In 1850 the elder Gross devised a special form of catheter for the relief of retention of urine due to blood-clot. He recommended it highly, and I have on several occasions found it very serviceable. It is of the same size and curve as the ordinary metal instrument; it has no eye, and the orifice at the vesical end is closed by means of an obturator. It is passed in the usual manner into the bladder, and by depressing the handle well between the thighs the point is passed through the blood clot lying at the base of the organ until it reaches the supernatant liquid, where by means of the mechanism connected with the handle the little button which closes the vesical end is made to project, leaving an orifice through which the urine can flow into the catheter. When the blood has been but recently effused Gross advised "that from six to eight hours be allowed to elapse so that the blood may subside and clot in the bottom of the bladder before the instrument is used." When active hemorrhage exists, with a tendency to the formation of obstructive clots, attempts are to be made to prevent this condition by means of irrigation with hot hæmostatic agents and the establishment of continuous drainage. It is in cases of vesical tumor attended with a constant and free hemorrhage followed by rapid formation of clots, that this instrument finds its greatest use.

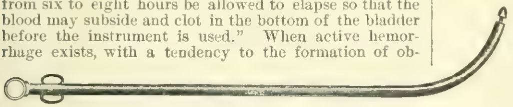

Fig. 1181.—S. D. Gross' Blood-Clot Catheter.

When retention is due to a tortuous stricture of small calibre, bougies about the thickness of a broom straw, called from their size "filiform bougies," are employed. They are made of catgut, rubber, or whale-bone. Those manufactured from the last-named material are the most durable and in most general use.

The filiform bougie should be eighteen inches in length, well rounded, perfectly smooth, and polished. If it be rough, chipped, or fractured it should not be employed, but discarded as worthless. Irregularities on the surface are not only apt to arrest the progress of the tunnelled instrument, which is passed over the bougie as a guide to the opening of the stricture, but, by the sudden arrest of the instrument at the point of obstruction, it is apt to cut the filiform, leaving a portion of the latter in the urethra, which may prove very difficult to remove. I have met in consultation with two cases in which this accident occurred. In one instance a portion of the filiform was broken off in the urethra. It could not be removed at the time with the instruments at hand and the patient was kept at rest until the proper utensil could be procured. In the mean time in attempting to pass water the fragment of the filiform was voided. In the second case the filiform was broken off in the clasp of a tight stricture; the patient was etherized and the stricture rapidly dilated in the hope of securing the broken portion. In performing this operation the piece of broken filiform was pushed into the bladder. It apparently gave rise to no pain or inconvenience and the individual was opposed to any further efforts toward its removal. The stricture was kept well dilated by means of steel bougies, and three weeks later the fragment was passed during the act of urination. Filiform bougies are generally straight, and they are then made to terminate in an olivary tip with a narrow, well-rounded neck. In order to facilitate the passage of the instrument through very tortuous strictures, the end of the beak is sometimes slightly angled or twisted, as is shown in Fig. 1182.

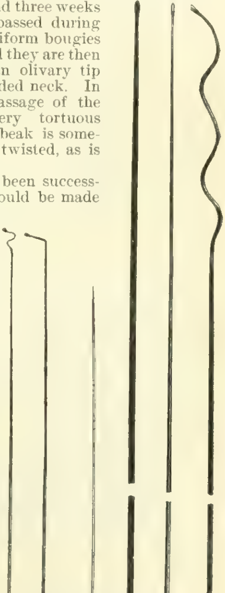

Fig. 1182.—Filiform Bougies, Olivary, Angled and Twisted.

After the filiform has been successfully passed an effort should be made to slip over it a tunnelled catheter constructed for the purpose; the bougie is then to be used as a guide. If this can be accomplished the urine can be evacuated, the catheter removed, and an attempt made to dilate the stricture by the passage of a tunnelled catheter of larger size. In some cases it will be impossible to pass the catheter through the stricture; the filiform may then be fastened *in situ* and the patient given a hot bath, after which he should be wrapped in blankets, and a hot lemonade, containing half an ounce of whiskey, together with one-quarter grain of morphine and ten grains of quinine, should be administered. He should be encouraged to sweat freely. In the majority of cases it will be found that in a short time the urine will begin to drop from the end of the filiform by capillary attraction, and gradually the pressing symptoms will be relieved. Should the bladder be greatly distended, and the symptoms urgent, and should it be found impossible to pass the tunnelled catheter over the filiform, through the stricture, into the bladder, the bougie may be fastened in the urethra and either the bladder aspirated, or an external perineal urethrotomy or a suprapubic cystotomy performed. As to the best course to pursue, the surgeon must be guided in each case by the cause of the retention, by the age as well as the condition of the patient, by the symptoms, and by the length of time that the retention has existed.

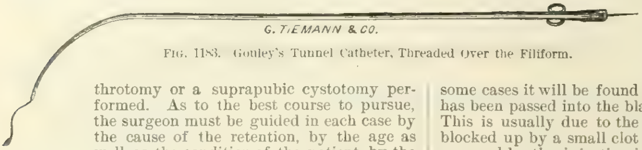

FIG. 1183. Gouley's Tunnel Catheter, Threaded Over the Filiform.

The utensil which is passed over the filiform bougie as a guide is known as the "Gouley tunnelled catheter." These instruments vary in size from No. 8 up to No. 18, French scale, and consist of a catheter with a Thompson curve but short beak. The eye of the instrument is occluded by an obturator, which can be removed after the catheter has been introduced, allowing the urine to flow. At the vesical end is a short tunnel which terminates in a groove passing along the back of the catheter. The loop at the end, which is the beginning of the tunnel, is threaded over the filiform which serves to guide the implement directly to the opening in the stricture. These catheters are used not only for the relief of retention of urine, but in the treatment of stricture of the urethra by gradual dilatation.

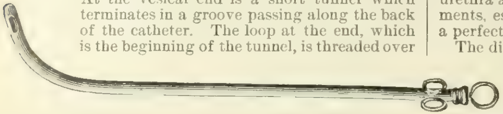

FIG. 1184.—Mercier's Invaginated Catheter.

A very useful and practical instrument, which has been wellnigh lost sight of by the profession, was devised in 1850 by Mercier for the purpose of relieving retention of urine in cases of prostatic hypertrophy in which a false passage exists. It is known as Mercier's invaginated catheter. It consists of two catheters, one made of metal and the other of gum. The one made of metal, usually spoken of as the "male catheter," should be eleven inches long, slightly curved, with an oval eye near to the vesical extremity. From the eye to the tip the instrument is made to slant with the object of tilting the end of the gum catheter forward when it is passed through the metal tube. The gum catheter is eighteen inches in length and is known as the "female catheter." It should be smaller in circumference than the male and when passed into the male instrument should fit loosely. The gum catheter should have an eye one-eighth inch from its end. The method of employing these instruments consists in first passing the gum tube into the male until the former almost reaches the eye of the latter. The male catheter is then passed into the urethra until its tip becomes inserted in the false passage, thereby blocking it up and preventing the further progress of the instrument. The gum catheter is now gently pushed onward until its tip emerges from the eye of the male catheter, which tilts the beak upward and allows it to pass forward, along the urethra, into the bladder. After the water is drawn the gum catheter is first removed; the metal instrument is to be withdrawn, or, if continuous drainage is desired, the male catheter may be gently removed, leaving the gum instrument in place. In some cases it will be found that after the gum catheter has been passed into the bladder the urine will not flow. This is usually due to the eye of the instrument being blocked up by a small clot of blood, which can easily be removed by the injection into the catheter of a syringeful of warm distilled water. Blood clots and fragments of stone after crushing operations are removed by the large metal catheter of the Bigelow evacuating apparatus. Gentleness and a thorough practical knowledge of the anatomy of the urethra are necessary in the employment of these instruments, especially when the attempt is made to introduce a perfectly straight tube.

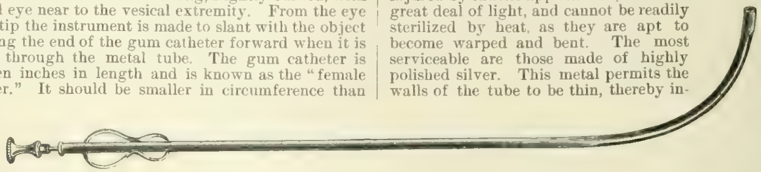

FIG. 1185.—Gouley's Tunnel Catheter, with the Stylet in Place.

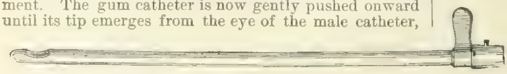

FIG. 1186.—Evacuating Catheter (Straight).

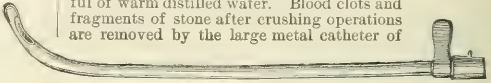

FIG. 1187.—Evacuating Catheter (Curved).

The direct visual examination of the urethra, by the insertion of hollow tubes constructed for the purpose, by means of which the canal can be illuminated either by reflected light or directly by means of a small electric lamp affixed to the end of the tube, is called "endoscopy"; while the instrument employed for the purpose is known as an "endoscope." Endoscopes are straight, cylindrical tubes varying in calibre and length to suit the size and portion of the urethra that it is desired to examine. They are made either of hard rubber or of various metals. Those manufactured from rubber are not recommended. They are injured by caustic applications, absorb a great deal of light, and cannot be readily sterilized by heat, as they are apt to become warped and bent. The most serviceable are those made of highly polished silver. This metal permits the walls of the tube to be thin, thereby increasing the bore of the instrument and serving to make it of light weight. These instruments are easily sterilized and but slightly acted upon by caustics and acids. The most improved endoscope carries a light at the end of the tube. The most satisfactory instrument of this kind yet devised is that of Valentine, with Koch's tubes, in which the entrance of light is so arranged as not to interfere with the application of medicaments to any portion of the urethra. An endoscope

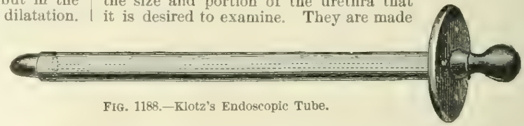

FIG. 1188.—Klotz's Endoscopic Tube.

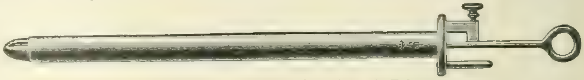

FIG. 1189.—Oberlaender's Endoscopic Tube.

exposes to view only a small portion of mucous membrane which appears at the vesical orifice of the instrument, but by moving it forward and backward the entire canal can be gradually inspected from the posterior urethra to the meatus. Endoscopic tubes are provided with obturators by means of which the vesical orifice is closed, thus facilitating the introduction of the tube into the urethra. The obturator may consist of a solid plug, made of hard rubber, or of a strong wire rod on the end of which is an olivary bulb of sufficient size to close the end of the tube. The bulb should have a deep slit corresponding with a similar one on the handle, so that the air may be allowed to enter the tube, thereby rendering the removal of the obturator easy and avoiding the danger of injury to the mucous membrane of the canal by suction.

The endoscope is manipulated on exactly the same principle as is the straight evacuating catheter of the Bigelow apparatus.

To perform catheterism skilfully it is essential that the operator should have a good practical knowledge of the anatomy of the urethra, as well as of its relations to the adjacent urinary organs.

When an attempt is made to insert an instrument of any kind into the urethra the utmost gentleness should be observed. It should be passed slowly, so that if an unexpected obstruction is encountered, the danger of injuring the canal may be avoided; force should never be exerted unless the operator is a surgeon of large experience in urethral instrumentation. Even in the most proficient hands injury may be inflicted by the employment of too much violence. It should be borne in mind that an instrument can be gently guided through the urethra when an obstruction exists, but it cannot be forced through without danger. When a novice first attempts catheterism, if it is found that an obstruction exists which prevents the easy introduction of instruments, it is wiser to seek the assistance of one who has had extensive experience in urethral surgery, rather than to persist in fruitless efforts to pass through the impediment; an attempt of this kind frequently results in traumatism, accompanied by hemorrhage, irritability, congestion of the mucous membrane, and a spasmodic condition of the urethra. The physician should always bear in mind, when dealing with urethral cases, that if he cannot benefit his patient he must at least be careful not to inflict unnecessary injury, as is unfortunately often done.

The elder Gross, in his "System of Surgery," has emphasized the fact that but few physicians pass a catheter skilfully when he says: "The introduction of a catheter, although apparently very simple, is one of the most delicate operations in surgery. It requires skill of the highest order, as well as an intimate knowledge of the anatomy of the urinary organs. *My conviction is that few men do it well.*"

In practised hands the sense of touch becomes so greatly developed that the surgeon knows with certainty exactly what portion of the urethra is being traversed as the instrument passes along; consequently he is enabled to decide by the touch alone whether the catheter should be advanced or withdrawn, raised or depressed, or if it should be allowed to remain *in situ* until the muscular spasm has relaxed.

The urethra is a canal which extends from the meatus urinarius to the bladder. Its walls are in contact, except when separated for the passage of urine, or for the emission of semen, or distended by the introduction of instruments or other foreign bodies.

In the flaccid penis the urethra forms two curves, one in the penile portion, which is obliterated when erection takes place or when traction is exerted upon the penis by stretching it upward toward the middle line of the abdomen. This part of the urethra is freely movable; it is distensible, yields to pressure, and readily changes its course, without injury, when instruments are inserted. It is only by gross negligence that a false passage can be established in this section of the canal. The more fixed division of the urethra describes a curve, which is fully explained on page 748; it yields very slightly to the advancing tip of the urethral instrument, and consequently here false passages are not uncommon.

Anatomically the urethra is divided into three parts: the penile, the membranous, and the prostatic. For clinical purposes it has been divided into two, the anterior and posterior. The former extends from the meatus to the anterior layer of the triangular ligament. The latter is the portion beyond the ligament and includes the membranous and prostatic urethra. The length of the urethra varies in different individuals; it measures from eight to nine inches. The average length is eight and one-half inches. As a rule an obstruction met with over seven inches from the meatus may be regarded as arising from an affection of the prostate gland, usually an enlargement of the organ.

The penile urethra is generally six and one-half inches in length. It is lined with a delicate mucous membrane, on the roof and floor of which are the openings of numerous ducts leading to the urethral glands; these are known as the glands of Littré. The urethra, in the spongy portion, is surrounded by involuntary, longitudinal, and circular muscular fibres, as well as by erectile tissue. The penile urethra has an expansion at either end. The dilatation back of the meatus is called the fossa navicularis, on the roof of which is a reduplication of the mucous membrane. It is valve-like in form and is called the lacuna magna. This fold, or pocket, is from one-half to three-fourths of an inch from the meatus, the distance varying in different individuals. It is the first point which is apt to catch the beak of an instrument and arrest its progress after passing through the meatus. It is for this reason that, when an attempt is made to insert a catheter, the tip of the instrument should be kept in contact with the inferior wall until the lacunæ are passed.

The bulbous portion, or the corpus spongiosum, is the termination of the penile urethra. It lies directly in front of the anterior layer of the triangular ligament. Here the spongy urethra terminates and the membranous portion begins, forming what is known as the bulbo-membranous junction; a very common site for an organic stricture of small calibre, and for the formation of false passages by urethral instrumentation.

The membranous portion of the canal joins the bulb at its upper rather than at its lower part, forming a dilatation on the inferior wall like a pouch or pocket. As men advance in years, especially if they have practised auto-catheterism for some time, this pouch becomes dilated, particularly on the floor of the urethra; it frequently acts as an obstruction and gives rise to a good deal of difficulty when one attempts to make an instrument glide past the spot. Occasionally small depressions, surrounded by folds of mucous membrane, are found on the floor of the bulbous urethra. When inflammatory conditions exist these folds become œdematous and increase the difficulty of instrumentation. These obstacles can generally be overcome by keeping the penis on the stretch and maintaining the beak of the instrument in contact with the superior wall of the urethra.

In old men in whom an obstruction at the bulbous urethra exists, and who are required to perform catheterism daily, an irritation is produced which is frequently attended by a low grade of chronic urethritis. As a result, a stricture forms, and this, in conjunction with the abnormal dilatation at the bulbous portion, renders catheterism extremely difficult.

The bulbo-membranous junction of the urethra is in contact with the anterior layer of the deep perineal fascia. When catheterism with a metal instrument is attempted, the beak touches the point of junction, the handle being well depressed between the thighs. The layer of fascia acts as a fulcrum and turns the point upward toward the opening of the membranous urethra, thereby assisting its onward passage toward the bladder. When the bulb is unusually enlarged, the fascia, instead of being an assistance to the passage of an instrument, acts as an obstruction, preventing its further transit and favoring the formation of a false passage if undue force is exerted.

Especially is this true if a stricture of small calibre is also present.

When a false passage is produced, the operator will become aware of the fact by the sudden interruption to the further progress of the instrument, together with the great local pain that immediately ensues. In addition the proximal end of the instrument will deviate from the median line. If a false passage has been made in the posterior urethra it can readily be detected by a rectal examination. As a rule, hemorrhage does not make its appearance until after the instrument has been withdrawn. It will vary in quantity from a few drops to a continuous flow, depending on the portion of the periurethral structures which has been injured.

Catheterism of the urethra in which a false passage exists generally requires an instrument with a large curve in order to reach the bladder.

The membranous urethra is usually three-fourths of an inch in length. It lies between the anterior and posterior layers of the triangular ligament, which serves to hold it firmly in place. This portion of the canal, together with the prostatic urethra, is frequently spoken of as "the deep" or "fixed urethra." It is composed of a mucous coat, submucous tissue, a few involuntary muscular fibres, and a thin layer of vascular tissue, which bleeds freely when injured. The membranous urethra is less movable than the prostatic portion; it is surrounded by a band of strong muscular fibres called the compressor urethræ. The filaments of this muscle pass over, under, and around the urethra; they aid not only in retaining the urine when the bladder is distended, but also in protecting the entrance of the posterior urethra from the invasion of foreign bodies and urethral instruments which are being roughly manipulated.

It is a voluntary muscle, being under the control of the will. It is markedly influenced by reflex action, giving rise to spasm, which accounts for the retention of urine which is observed occasionally in acute urethritis and after the use of strong injections, and which sometimes follows operations on the abdominal cavity, rectum, genital organs, and lower limbs.

The passage of either a catheter or a bougie is rendered difficult when resistance is offered by the firm contraction of the muscular fibres, when hyperæsthesia of the posterior urethra exists in nervous, impressionable individuals, or when rough instrumentation is used. It is usually at the bulbo-membranous junction that the most difficulty is experienced when catheterism is attempted. Strictures of the membranous portion of the urethra are usually of traumatic origin. The prostatic urethra is about one inch and a quarter in length; it is somewhat longer in cases of prostatic hypertrophy. It is more movable than the membranous portion. It is frequently the site of traumatism and false passages made by the ignorant and by rough use of urethral instruments. The prostatic urethra passes downward and forward and becomes the membranous urethra on reaching the posterior layer of the triangular ligament. The interior wall shows various deep depressions. In rare instances the mouth of the ejaculatory ducts are widely dilated and offer an obstruction to catheterism when attempted. While an instrument is passing through the prostatic urethra the tip should be kept in contact with the superior wall.

From what has been said it will be understood that the urethra is not a tube of uniform calibre, but consists of a series of physiological dilatations and contractions. This is well illustrated in the following classification given by Taylor, showing the calibre of the different portions of the canal:

	Millimetres.	Calibre.
Meatus	7- 9	21–28 F.
Fossa navicularis	10–11	30–33
Middle of pendulous portion	9–10	27–30
Bulb	11–12	33–36
Membranous urethra	9	27
Apex of prostate	10	30
Middle of prostate	15	45
Vesical end of prostate	11	33

An examination of the anatomical construction shows that one is dealing with a tube which presents two marked constrictions and three dilatations, as well as a movable and a fixed curve; the constrictions being found at the meatus and internal vesical sphincter, the dilatations at the fossa navicularis, bulb, and middle portion of the prostatic urethra. The fixed curve begins one-half inch in front of the bulb. These facts should be borne in mind by the operator.

The difference between the superior and the inferior wall of the urethra is an anatomical point of great importance. The superior wall is smoother, less vascular, not so intimately connected with the important structures, is more constant in form and regular than the inferior wall, which presents a series of broken lines due to depressions. The curve of the urethra remains regular only on the superior wall, which is the shortest route to the bladder. The dilatations of the urethra take place at the expense of the inferior wall, and they assist in causing its irregularities. The greater the curve of the urethra the greater its length, in consequence of which the depressions in the bulbous and prostatic portions of the canal will be more marked.

In selecting the size of the catheter or bougie to be employed the operator may be guided by a law first enunciated by Otis in 1883, in which he demonstrated that the calibre of the urethra bears a constant relationship to the circumference of the flaccid penis. He gives a scale exhibiting the relative proportion between the circumference of the penis and the calibre of the urethra. In my opinion the ratio laid down by Dr. Otis is too large; that suggested by White in Morrow's "System of Genito-Urinary Diseases" is more reliable (*loc. cit.*). It is as follows:—

"Circumference of penis, middle of spongy portion, 3 inches; calibre of urethra, 26–28 mm. Circumference of penis, 3¼ inches; calibre of urethra, 28–30 mm. Circumference of penis, 3½ inches; calibre of urethra, 30–32 mm. Circumference of penis, 3¾ inches; calibre of urethra, 32–34 mm. Circumference of penis, 4 inches; calibre of urethra, 34–36 mm. It is seldom necessary to go beyond this last size."

Phimosis, either congenital or acquired, may contract the orifice of the prepuce to such a degree that it will be impossible to locate the meatus. When this condition exists the foreskin may be divided on the dorsum sufficiently to render the opening visible, or if necessary circumcision may be performed.

In some instances an œdematous condition of the foreskin, due to inflammation, may render it impossible to find the meatus. The obstruction is due in part to an elongation of the prepuce, and also in part to the fact that the preputial orifice is contracted. If, after the foreskin has been retracted as far as possible, the meatus cannot be found, an attempt should be made to lessen the amount of serous effusion in the organ by pressure. This may be effected by grasping the penis firmly with the left hand, retracting the prepuce as far as possible, and making continuous pressure on the organ. Some surgeons advise the application of a broad elastic band. When pressure applied in the manner indicated fails, the skin of the penis should be sterilized and multiple punctures should be made in the vicinity of the prepuce with an aseptic tenotome, which allows the serum to escape. After this operation the foreskin can be retracted to such an extent that it will be possible to locate the meatus. When the glans penis is covered with papillomatous growths difficulty in finding the meatus may be experienced; usually under these circumstances the meatus can be detected by means of a probe.

Catheterism should always be performed with the patient lying in the recumbent posture. Unexpected and serious symptoms sometimes arise suddenly from urethral instrumentation despite the utmost gentleness and care. Individuals liable to be so affected are usually of a neurasthenic type, but these symptoms may arise in strong, robust men in whom no cause for their appearance can be found. Shock more or less severe, epileptiform convulsions, and even death have been known to follow the introduction of an instrument into the urethra.

It is always well to have the shoulders slightly elevated, whereby the abdominal muscles are relaxed and the tension on the suspensory ligament is relieved. Flexing the thighs also aids in relaxing the abdominal muscles. The patient should be instructed to open the mouth widely and to take full, quick inspirations, which will relax the diaphragm and subdue muscular tension, in addition to occupying the mind, so that attention is diverted from the affected parts.

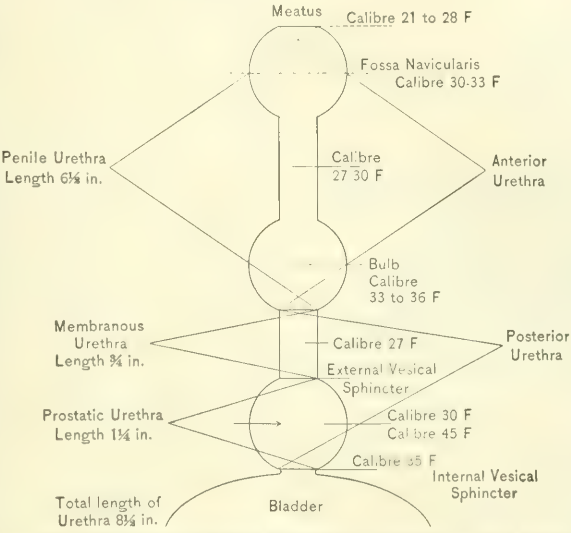

FIG. 1190.—Showing Normal Physiological Constrictions and Dilatations of Various Portions of the Urethra, with the Calibre and Length of Each. (Horwitz.)

The method to be employed when one undertakes to carry out urethrovesical catheterism will depend on the character of the instrument to be used, whether it be soft, flexible, metal, straight or curved. It has already been shown that the calibre of the urethra is a variable one; that it consists of a series of physiological contractions and dilatations; that the dilatability possesses a relation to the circumference of the flaccid penis. As a rule, the external meatus is the most contracted portion of the canal. It will frequently be found to vary in size; in some instances being unusually large and in others abnormally contracted. It is a safe rule to regard an instrument to be of a proper calibre when it can be readily inserted through a normal meatus and passed through the entire canal without encountering any abnormal obstruction. A normal meatus may, therefore, be taken as a guide for the size of the catheter to be employed. When the urinary outlet is abnormally contracted meatotomy should be performed.

Regarding the size of the catheter, every patient is a law unto himself, as no two individuals have a urethra of exactly the same calibre. All genito-urinary surgeons agree that a catheter should be neither too large nor too small; that the urethra should be moderately filled, but not dilated. The catheter which fulfils this indication can be inserted far more readily, will give rise to less discomfort and pain, and will involve less danger of producing a false passage or of causing attacks of urethritis and orchitis than will the use of very small catheters, which are so frequently employed by patients under the impression that they give less pain and are more free from danger. The calibre of the catheter suitable for the average individual is about 15 French.

Both soft and flexible catheters are passed in the same manner. The instrument having been sterilized and anointed with an antiseptic lubricant, and the patient having placed himself in the recumbent posture, the surgeon should stand on the left side and grasp the penis between the middle and ring fingers of the left hand, just behind the corona glandis, leaving the index finger and thumb free to retract the prepuce and separate the meatus. The penis should be stretched upward toward the middle line of the abdomen. The end of the catheter is then to be inserted and slowly and gently propelled forward with a uniform motion, introducing about a quarter of an inch of the instrument at each movement. This is to be continued until the bladder is reached. If any obstruction is met with the further progress of the instrument should be immediately arrested. It should be gently retracted for a short distance and then an effort should be made to reinsert it. After the instrument has been passed through the urethra and the urine evacuated, the proximal end of the instrument should be closed either by pinching the end of the instrument or by closing the orifice with the index finger, which prevents the urine that remains in the catheter from escaping when the eye of the catheter emerges from the meatus. When employing a catheter with a coudé curve, it should be recollected that the instrument is in contact with the two opposite walls of the urethra, so that when the bulbous portion of the canal is reached it should be more rapidly lowered toward the thighs than is the custom in employing other forms of catheter. If this advice be followed the instrument will pass readily into the membranous urethra.

Daily catheterism frequently gives rise to a low grade of chronic urethritis attended by a spasmodic condition of the urethra, rendering the operation painful. This condition is relieved by daily irrigation with a warm boric-acid solution, and by passing a conical bougie every third day. The spasm may be overcome by the administration of:

℞ Tinct. belladonnæ	ʒ ss.
Sodii bromidi	ʒ iv.
Liq. potassii	ʒ ij.
Syr. zingiberis	℥ iij.
Aquæ destil. ad	℥ vi.

M. Sig: Tablespoonful in water three times daily.

Gouley highly recommends gr. $\frac{1}{200}$ of hyoscyamus sulphate, to be given three times daily. He advises that the remedy should not be administered over three days in succession, when an interval of four days should be allowed to intervene before its administration is resumed.

Relapsing orchitis in old patients practising autocatheterism is due either to the use of infected instruments or to a too frequent use of the catheter. When this condition exists, the urethritis may be treated in the usual manner and continuous catheterism employed. In the aged, whose sexual powers have long been suspended, double vasectomy may be resorted to; for this not only prevents any further development of orchitis, but is oftentimes beneficial in causing atrophy of the hypertrophied prostate gland.

Patients suffering from the effects of residual urine due to prostatic hypertrophy should not employ a catheter too frequently. A number of individuals have come under my cognizance who were affected with urethrocystitis complicating an obstructive prostate gland, and who were in the habit of inserting the catheter at least once an hour. The too frequent use of the catheter undoubtedly increases the inflammation of the urethra and bladder. When the desire for urination is frequent and urgent, rendering the repeated introduction of a catheter necessary, the individual should be put to bed and continuous catheterism instituted until the inflammation at the neck of the bladder has subsided, after which some permanent relief should be afforded by an appropriate operation. In cases in which the urine is sterile the frequency with which catheterism may be resorted to is well formulated by White, who says: "When the urine is sterile it is rarely necessary to catheterize more than once in four hours. The frequency should be in proportion to the amount and character of the residual urine, a very good working rule being the use of the catheter once a day, preferably at bedtime, for three ounces, twice for six ounces, and then once more for every additional two ounces."

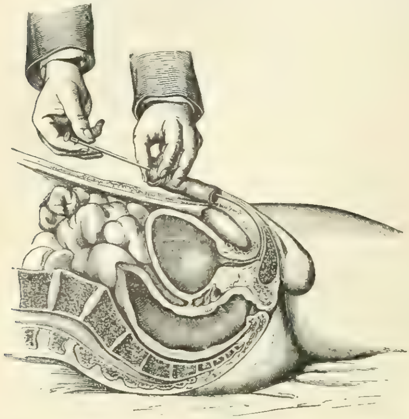

FIG. 1191. Showing Passage of a Curved Instrument through the Anterior Urethra. (Englisch.)

A curved metal instrument, whether catheter or bougie, is to be passed through the urethra on precisely the same principles as those which have already been stated. The patient is to be placed in the position which was recommended when I described the manner of introducing a rubber catheter. The surgeon stands on the left side, grasps the penis in the manner already described, and stretches it gently upward toward the middle line of the abdominal wall, thus obliterating the curve of the penile urethra and lessening the dilatability of the bulb. The proximal end of the catheter is held lightly in the right hand, with the handle well over the left thigh. The vesical end is then inserted into the meatus, and kept in contact with the floor of the urethra until the lacuna magna is passed and the curve of the instrument is fairly in the canal. The handle of the instrument is moved to the middle line of the abdomen, and the right hand gently, but firmly, and with uniform force, pushes the catheter into the urethra, at the same time stretching the penis gently on the shaft of the instrument until the right and left hands are about three inches apart.

The catheter continues to glide along the urethra until its onward progress is slightly retarded; which means that the beak has reached the sinus of the bulb, is in contact with the anterior layer of the triangular ligament, and is ready to pass through the fixed curve of the canal. The operator now takes hold of the instrument with the left hand and slowly and gently changes it from the horizontal to the vertical position, bringing it down between the thighs, when the catheter will pass through the membranous and prostatic portions of the urethra. The changing of the instrument from a horizontal to a vertical position brings the curved portion directly under the pubic arch, which is opposite the opening of the membranous urethra, behind the triangular ligament. Should any obstruction be met with at this point, no attempt should be made to carry the instrument onward until the temporary contraction of the compressor urethræ muscles has relaxed. If the retraction be due to the impinging of the tip of the instrument on the triangular ligament, it should be slightly withdrawn, the handle of the instrument well depressed between the thighs, bringing the tip of the instrument in contact with the superior wall of the urethra, when, by gentle pressure made in the axis of the body, it can be readily passed into the bladder.

Occasionally it happens that the dilated mouths of the ducts leading to Cowper's glands will be sufficient cause for the arrest of the progress of an instrument. When this occurs it will be found that the point of the instrument has deviated either to the right or to the left of the median line and that it is impossible to urge it onward. By slightly withdrawing the instrument and keeping the tip in contact with the anterior wall of the urethra, the obstacle will be overcome.

Should the instrument be arrested at the bulb, the right hand should be passed back of the scrotum and with it the shaft of the instrument raised, whereby its onward progress will be greatly facilitated. When the arrest is due to a prostatic hypertrophy, the index finger of the right hand may be inserted into the rectum and the catheter gently lifted upward, when it will advance without further trouble.

Englisch describes a rare form of obstruction which when present gives rise to a good deal of trouble. Owing to an unusually firm attachment of the penis to the symphysis pubis, by means of the suspensory ligament, a band is formed, and with it is associated a dilatation or pocket of the superior wall of the urethra, which is apt to catch the tip of the instrument and prevent its further progress. It is on lowering the beak of the catheter, in order to pass the obstruction, that a false passage is apt to be produced. When failure to pass a catheter is due to this cause, the right hand should be placed on the body of the penis, just in front of the symphysis, and the organ gently pressed downward; at the same time the instrument should be withdrawn about half an inch by means of the left hand; the handle of the catheter is then slightly elevated in order to place the tip of the instrument on the floor of the canal, after which it should be slowly pushed onward until the obstruction is passed.

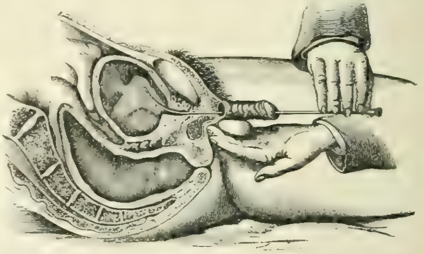

FIG. 1192.—Showing the Passage of a Curved Instrument through the Posterior Urethra. (Englisch.)

The dilated mouths of the ejaculatory ducts will in rare instances impede the passage of a catheter. Should this condition exist, the tip of the instrument must be kept in contact with the roof of the prostatic urethra. But it must be borne in mind that the superior surface of the prostatic urethra, especially in the posterior portion, is quite thin and can be easily punctured. It must always be recollected that perineal and scrotal tumors, as well as prostatic hypertrophy, change very materially the fixed urethral curve. When any of these conditions exists catheters with a curve suitable for the altered condition must be selected.

In most instances when the catheter reaches the bladder the urine begins to flow; after the instrument has entered the cavity, it will be found that it is freely movable along its axis, and that the beak can be readily turned in all directions.

When there is an enlargement of the middle lobe of the prostate gland, the urethra is elongated to a marked degree, and the operator may fail to draw off the urine owing to the fact that the catheter has not been introduced sufficiently far, or that it is too short to reach the distended organ.

Occasionally it will be found that after the catheter has entered the bladder the urine will not be expelled. This may be owing to many reasons. The most common cause is the blocking up of the eye of the instrument with either pus or blood. These obstacles may be overcome by passing through the catheter a warm five-per-cent. solution of boric acid. The failure to evacuate may be due to an atonied condition of the bladder, owing to a lack of proper muscular contractility of the walls of the organ. This difficulty may be surmounted by placing a hand on the abdomen just above the pubes and making gentle pressure over the distended viscus.

The eye of the instrument may be obstructed by coming in contact with the mucous membrane of the bladder. This condition may be readily obviated by giving the wrist a slight twist, or by moving the catheter back and forth. When the bladder is distended this impediment cannot arise. In rare instances the urine is lodged in a diverticulum. When this occurs the fluid cannot be reached by a catheter.

Suppression of the urine may be mistaken for retention. When suppression exists the characteristic symptoms of retention are absent; there is no pain, spasm, or sense of weight in the pelvic region. A constant desire to urinate, associated with tension, is present. There may be dribbling of the urine, or but a few drops are passed at a time, but there is never a full stream. There will be absence of the characteristic, hard, pyriform tumor, which is fluctuating, but not affected by change of posture, and which is always situated in the median line. The absence of these well-marked symptoms of retention should prevent any difficulty in making a differential diagnosis.

When residual urine is associated with an excessive enlargement of the prostate gland, the beak of the catheter, on entering the bladder, is liable to be high above the level of the fluid lying in the pocket at its base. When this condition exists, it is recommended that the individual be instructed to lie on his side, or to assume the "knee-chest position"; an attitude exceedingly unpleasant to many patients. The resort to such expedients shows that the time for operative interference has arrived.

In nervous patients, or in those in whom the urethra is inflamed or irritable, a urethral injection of one drachm of a two-per-cent. solution of cocaine should be administered, and it should be kept in contact with the irritated surface for the space of five minutes before instrumentation is attempted. An excellent local anæsthetic has been suggested by Lydston, who claims that "it is absolutely safe, free from constitutional effects; distinctly lessening the hemorrhage both before and after operation; and causing less disturbance of nutrition of the wounded tissues." It consists of a ten-per-cent. solution of antipyrin in one per-cent. solution of carbolic acid. The solution should be fresh and allowed to remain in the urethra for ten minutes. I have employed this frequently as a substitute for cocaine with most satisfactory results.

The passage of straight tubes through the urethra into the bladder requires a slightly different manipulation, and more skill than is needed for the introduction of curved instruments. The procedure is also attended by greater danger of traumatism. At the start a straight instrument is inserted into the urethra in the same manner as an ordinary catheter, except that it is entered parallel with the middle line of the abdomen and slowly passed into the urethra toward the rectum until it cannot be advanced any farther in that direction; it is then slowly brought from the vertical to the horizontal position, pressure being made at the same time with the right hand on the body of the penis directly in front of the symphysis pubis; which not only assists to relax the suspensory ligament, but helps to straighten the curve of the urethra. In order to be sure that the point of the instrument is not caught in the dilatation at the bulb it should be slightly withdrawn, the handle of the instrument being brought well down between the thighs, and then pushed gently upward in the axis of the body. In old men with a dilated bulbous urethra or a prostatic hypertrophy the passage of a straight catheter is often impossible.

In attempting to pass filiform bougies it is well first to distend the canal by gently injecting a syringeful of liquid aseptic cosmoline. The filiform is then introduced into the meatus and passed slowly down to the obstruction, the patient's face meanwhile being carefully watched for the slightest expression of pain; should this arise the onward passage of the filiform must cease. The least impediment to the passage of the bougie should warn the operator that he has introduced the instrument as far as is justifiable. A second filiform should then be introduced in the same manner, and the process repeated until six or eight whalebones have been inserted, when the operator gently tries each in turn to see if the opening in the stricture can be found. This manœuvre requires care and patience. Under no circumstances is force to be employed. The opening in the stricture may be situated above or below, or at the right or left of the centre. When the attempt is made to pass a filiform bougie the tendency is for the operator to work toward himself; consequently if the opening is on the right side, and if, after a fair trial, he finds that the attempt to insert the instrument whilst standing on the left of the patient fails, he should change his position to the other side of the patient. Upon renewing the attempt in this new position he will often find that the instrument will readily pass through the stricture.

In eccentric stricture the opening will probably be found by this manipulation. When the instrument glides through the contraction with little or no pain, and without force being required, it will pass into the bladder and be freely movable in the urethra. These instruments are frequently made with a spiral twist or angle at the end, on the supposition that the physician can more readily pass such a one should the stricture be eccentric. As a rule, the straight instrument is all that is required.

The failure on the part of many practitioners to use successfully filiform bougies is owing to several reasons: The instruments sold in the shops are more often than otherwise worthless; they are too stiff, not well rounded, do not terminate in a proper neck, and are generally too large to serve as guides to small-sized tunnelled catheters which are designed to pass over them. The surgeon should make his own filiform bougies; a dozen properly constructed will, with ordinary care, last through several years of active practice. An important rule to follow is to employ the filiform before a bougie, catheter, or any other instrument has been passed into the urethra. If an instrument has been previously used it will generally be useless to attempt the passage of the filiform; failure being the usual result. The operator must not be sparing of his time in these cases; infinite patience is a necessary element of success.

To introduce a tunnelled catheter successfully over the filiform and through the stricture the instrument should be gently passed down to the obstruction, then transferred from the right to the left hand, and whilst the hand holding the penis puts it on the stretch the filiform is slightly withdrawn about a quarter of an inch, and then both filiform and tunnelled catheter are to be carried together through the stricture. This procedure prevents the catheter from cutting the filiform in two and assists in guiding the instrument through the obstruction.

Catheterism in children must be very gently performed, as the urethra at the bulbo-membranous junction is very easily torn. Keegan has pointed out that the capacity of the urethra varies in children of the same age much more than does that of the adult. Litholapaxy in children has proven that the dilatability of the urethra is far greater than was formerly supposed. Freyer reports a successful case of litholapaxy in a child eighteen months old. Catheterism in children is to be conducted on the same principles as those which guide us in performing the operation in the case of an adult; the utensil used must be of a size suitable to the calibre of the urethra. When curved instruments are employed, the arc should be increased over that of the ordinary normal bend of the urethra and should describe the arc of a smaller circle.

Catheterism in women, as a rule, is easily accomplished by touch, without the assistance of the eye. It is difficult to locate the meatus in old women, especially if they have borne many children, the landmarks being obliterated, and the meatus being removed farther back than is normal. The dilatation of the mouths of the ducts leading to the glands situated in the vicinity of the urethra; an anteflexed uterus; hypertrophy and cysts of the labia; papillomatous growths or cicatrices in the vicinity of the meatus—all these may render it very difficult or even impossible to locate the urinary opening by the sense of touch. When any of these conditions arises I am averse to catheterism being performed by touch. It is fraught with danger to the patient; infection of the badder being very apt to ensue. I have seen many cases of cystitis in women thus produced. Before the catheter is used the external genitalia should be carefully sterilized and if practicable a vaginal douche should be administered. Especially is this to be done after childbirth, and following operations on the uterus, vagina, and external genitalia, or when the patient is suffering from some specific inflammatory condition. When attempts are made to pass the catheter by the sense of touch, the operator is unable to determine whether the pathological secretions have been removed and the parts properly cleansed before he inserts the instrument. There is always more or less uncertainty in at once locating the meatus; the instrument is apt to be thrust in different directions before the opening is located. If the vulva and vagina have not been properly sterilized an infected catheter will assuredly be inserted into the bladder; hence it should be insisted on in every case that female patients be catheterized by aid of the eye rather than by touch. To pass the catheter by touch, the woman lies on her back with the thighs slightly flexed and the knees elevated. The thumb and index finger of the left hand separate the labia. The middle finger is then inserted into the vagina and passed backward and upward until the superior wall is reached; it is then to be brought forward until the depression in which the meatus is situated is felt. This spot having been determined, the finger is passed a little backward and held firmly in place while the catheter, which is in the surgeon's right hand, is passed over the finger, which is in contact with the upper wall of the vagina, and serves to guide the instrument into the urethra. After it has entered the meatus the instrument should be carried backward, upward, and then directly backward. When the instrument is to be passed by sight, the patient is brought to the edge of the bed, the legs are flexed, and the feet allowed to rest on the side of the bed. The genitals are cleansed and sterilized and the labia well separated by the index finger and thumb of the left hand. If the genital organs are in normal condition the meatus comes at once into view, when the catheter can be readily inserted. Female catheters are straight tubes made of either glass, silver, or German silver, the former being preferable. They should be six and one-half inches in length and 14 F. in circumference. They are always to be sterilized by boiling. When abnormal conditions exist, it may be necessary to employ either a male soft rubber or a flexible woven catheter.

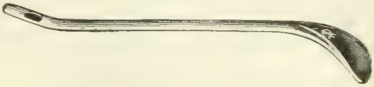

FIG. 1193.—Sims' Female Catheter.

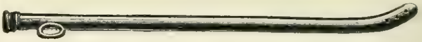

FIG. 1194.—Ordinary Pattern of Metal Female Catheter.

The durability and usefulness of rubber urethral instruments depend on the care taken to preserve them. In order to employ catheterism with safety to the patient, it is essential that the surgeon should be thoroughly familiar with the modern methods in vogue for the preservation and sterilization of instruments, and for the proper sterilization of the urethra and hands of the operator. Like all other surgical procedures, aseptic catheterism requires that the hands of the operator, the instruments employed, as well as the preputial fold, glans penis, and urethra, should be rendered as nearly sterile as possible.

Unfortunately the urethra is the normal habitat of a variety of micro-organisms, some of which are harmless, while others become virulent when the physiological resisting power of the urethra is lowered by injury or disease. It is probable that when the urethra is in a pathological condition, the intra-urethral microbic life increases in activity, and also that the micro-organisms that were apparently harmless in the normal condition become virulent. The introduction, into the canal, of infected instruments producing slight traumatism from careless handling, or an abrasion of the mucous membrane from friction, may cause not only constitutional infection, giving rise to some of the various forms of urethral fever, but also secondary infection of some of the adjacent urinary organs which are connected with the urethra. Lustgarten, Mannaberg, Melchior, Legroin, and others have conclusively demonstrated that the urethra normally contains, among other forms of micro-organisms, staphylococci and streptococci, which in all probability become active when infected instruments are inserted into the healthy urethra. Dirty instruments, especially if they injure the mucous membrane at the same time, both give rise to a suitable soil for the nidus and growth of these microbes, and at the same time introduce into the urethra pathogenic micro-organisms which were not present previous to the passage of the catheter.

Many persons have contracted virulent gonorrhœa in this manner. In one instance, which I saw in consultation, violent infection followed the insertion of a steel bougie; it produced cellulitis, gangrene, and sloughing of the under portion of the corpus spongiosum, with extensive hypospadias—conditions which rendered necessary several plastic operations before the cure of the case was completed. Besides the micro-organisms enumerated a bacillus is found so closely resembling the tubercle bacillus that it is nearly impossible to distinguish between them. It is probably a smegma bacillus. Its presence is frequently the cause of a mistaken diagnosis of tuberculosis of the genito-urinary tract. There are also several varieties of diplococci which so closely resemble those of Neisser in every respect that in some forms of chronic urethritis they cannot be distinguished from the gonococci. From what has been said it is evident that it is impossible to render the urethra aseptic; therefore the term "aseptic catheterism" is a misnomer. A catheter may be made aseptic, but efforts made to sterilize the urethral tract are abortive. Unfortunately, antiseptic remedies of sufficient strength to render the urethra sterile cannot be employed. When the urine is alkaline and purulent, much may be accomplished by the internal administration of such remedies as have a tendency to sterilize the urine. At the same time irrigation with any weak antiseptic solution should be employed, and the instruments and the surgeon's hands should be thoroughly cleaned and sterilized.

Since the introduction of antiseptic methods of catheterism, not only has the mortality of urethral operations materially diminished, but patients make a more rapid convalescence; in most instances they escape urethral fever and such complications as urethritis, prostatitis, cystitis, orchitis, and infection of the kidney. Evacuating catheterism can be performed with less danger to the patient, cystitis and orchitis being infrequent complications under these circumstances.

When the urine is alkaline, containing pus or blood, especially if the microscope reveals the presence of the bacillus coli communis, the employment internally of such remedies as quinine, boric acid, salol, eucalyptus oil, and urotropine is indicated; the latter remedy is the most efficient. When the gonococci are present, methylene blue, given separately or in combination with cubebs, copaiba, or sandalwood, is frequently of service. The hands of the surgeon should be carefully washed and scrubbed with soap and water, especial attention being given to the subungual spaces. Afterward they should be rubbed with a piece of sterilized gauze saturated with alcohol, with a view to dissolving the fatty matter of the skin, thereby removing the material which serves to shelter microbic life. In order to perform catheterism with the least danger of infection, it is essential that the hands should be as clean as soap and water can make them; it is not necessary to complete the sterilization by immersing them in a solution of the bichloride of mercury, unless some more formal operation is to be performed.

As microbic life swarms in the vicinity of the foreskin, preputial folds, and glans penis, the parts should be thoroughly washed with soap and water, and then bathed with a solution of bichloride of mercury of a strength not greater than 1 to 5,000. Care should be observed not to allow the solution to be introduced into the urethra; severe urethritis might be produced. Antiseptic solutions which are employed to irrigate the urethra should be very weak. A corrosive sublimate solution should never be stronger than 1 to 20,000. Irrigation with a solution of the strength advised is indicated before an operation on the urethra, prostate gland, or bladder is commenced. It is sometimes beneficial in tuberculous lesions of the genito-urinary tract. It should not be employed as a daily irrigation by patients who practise auto-catheterism, as its continuous use is apt to give rise to urethritis. Permanganate of potassium solution may be employed in varying strength, from 1 to 5,000 to 1 to 2,000. In a solution not stronger than here indicated it can be used daily with great benefit, rarely giving rise to irritation. Nitrate of silver solution of a strength of 1 to 10,000 is sometimes employed, especially when chronic inflammatory conditions of the urethra and bladder exist.

One of the least irritating and most satisfactory cleansing solutions, when the catheter is being used daily, is a warm five-per-cent. solution of boric acid. If there is no infection of the urethra nothing is more serviceable, previous to catheterism, than an irrigation with a warm normal salt solution.

Beck, in the *Medical News* for January, 1900, has suggested the prophylactic injection of a five-per-cent. emulsion of iodoform and glycerin before the introduction of an instrument into the urethra. He claims that "if an abrasion is caused the iodoform will come in contact with the wound at the very moment when it is made and with the wound serum at the stadium nascendi. Iodine is set free and during this chemical process bacteria are destroyed or the development at least is arrested." This is an excellent suggestion, and I have often employed the remedy, but patients frequently object to its use on account of the disagreeable smell of the iodoform.

It is useless to expect the patient to sterilize the external genitals and urethra whenever the catheter is to be inserted; nor is this absolutely essential. If the individual can be impressed with the danger of neglecting the ordinary methods of cleanliness, there will be but little difficulty in getting him to wash and cleanse the parts at least once or twice a day and to use only sterilized undamaged catheters. In cases in which the patient is able to pass his urine, but in which catheterism is necessary, it is well to instruct him first to urinate, thereby "flushing" the urethra before the canal is irrigated preparatory to the introduction of the instrument. In cases of retention of urine the urethra in front of the obstruction should always be irrigated with either the salt or the boric-acid solution previous to instrumentation. In retention due to acute urethritis the canal should be irrigated with a solution of permanganate of potassium not stronger than 1 to 3,000 before attempting catheterism. A catheter which has been employed in a case of retention of urine due to acute gonorrhœa should immediately be sterilized by boiling after using, when it may be laid aside until it is determined whether its employment is again necessary. It should be used on but one individual.

The preservation and durability of soft-rubber and web catheters depend on the manner in which they are cared for. Rubber or gum-coated catheters should never be coiled; they should be kept at full length, perfectly straight; means being taken to prevent them from coming in contact with each other. As soft-rubber catheters when exposed to the air undergo oxidation, it is essential after they have been sterilized that they should be wrapped in moist sterilized gauze and secured in tightly closed glass tubes. Englisch states "that vulcanized caoutchouc catheters are best preserved in asbestos."

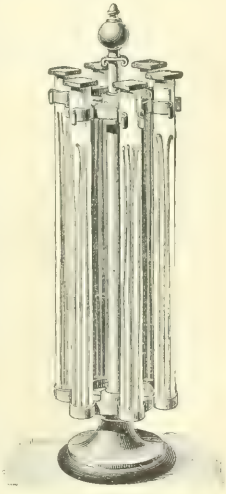
FIG. 1195. Hermetically Sealed Glass Tubes for Storing Sterilized Catheters, with Convenient Form of Stand.

Web catheters are stored in the same manner. Coiling these instruments causes their gum coatings to crack, thus rendering sterilization impossible and increasing the chances of their injuring the urethral mucous membrane. If a soft-rubber instrument has become hard and brittle, or if it is greatly lengthened and softened by the use of the lubricants employed, it should be discarded. Flexible instruments should not be employed when the coating is not perfectly smooth or if they show the least abrasion, fissure, or crack.

Soft-rubber catheters may be sterilized by boiling for five minutes; they are not injured by the process. The finest grade of web catheter will withstand boiling without injury unless it be repeated too frequently or continued for too long a time, when the coating is liable to become blistered and the instrument rendered worthless. After a rubber or web catheter has been employed it should be thoroughly washed with soap and water and a full stream of water allowed to flow through it. It is then placed in the glass cylinder known as a "catheterostat," which serves for both a sterilizing and a storing jar. It was devised by Frank and Dufaux. It consists of a glass cylinder sixteen inches long, having on the inside near the rim a shelf on which rests a perforated metal plate for holding the rubber instruments. In the bottom of the jar is placed a dozen tablets of trioxymethylene, which is a derivative of formal. It has been demonstrated by the experiments of Janet and Guyon that this antiseptic is the least harmful and the most efficient that can be employed for catheters of ordinary calibre. An exposure to the fumes of these tablets for twenty-four hours is sufficient, unless the instruments be of very small calibre, when they should be allowed to remain exposed to the sterilizing fumes for at least three days. These exhalations are given off at a temperature above 56° F.; below this point vaporization does not take place. The apparatus should, therefore, be kept in a warm room. The tablets preserve their efficiency for a long time and waste imperceptibly.

A metal box for the purpose of sterilizing rubber urethral instruments has been devised by Janet. It is of two sizes. The larger is for hospital use; the smaller for patients who have recourse to auto-catheterism. The box is seventeen inches long, three inches high, and three inches wide, and rests on four metal feet. It is closed at both ends, one extremity having a tightly fitting metal cap attached which can be removed when access to the interior is desired. The interior is furnished with two shelves which are perforated by holes; on these shelves the catheters are to be placed. In addition there is, at the bottom, a shelf covered with a perforated metal screen on which can be placed trioxymethylene tablets; or it may be covered with flannel which can be moistened with liquid paraform or covered with a powder of formal.

Patients who require the use of a catheter four times daily should have eight catheters, four to be placed on the upper and four on the lower shelf of the apparatus. At the end of twenty-four hours the instruments are ready for use. During the day the four catheters on the upper shelf are to be used, washed, and put aside; at the end of the day they are replaced on the empty shelf. On the following day the instruments on the lower shelf are to be employed, thereby allowing an opportunity for the catheters on the upper shelf to be resterilized and rendered ready for service when needed. If the catheters are not to be frequently used the instruments should be allowed to remain in either the closed catheterostat or in the metal box until thoroughly antisepticized, when they should be removed, wrapped in sterilized gauze, and placed in tightly corked glass tubes ready for use. By this means the surgeon has his rubber urethral instruments always prepared for any emergency that may arise. Before using the urethral instruments that have been sterilized by formalin or its derivatives, they should be either thoroughly washed with a five-per-cent. boric-acid solution or placed in a tin cup containing boiling water for at least five minutes: as in many instances the formalin deposited on the catheter proves irritating to the mucous membrane of the urethra. This is especially necessary in the case of those who require daily catheterism and in whom frequent introduction of the instrument is necessary. For patients whose duties necessitate their absence from home and who cannot have access to sterilized catheters, a papier-maché pocket case has been devised which is light and can be conveniently carried; the instruments in this case are kept in an aseptic condition. It holds four instruments which are curved, but not bent; it is supplied with a pocket in which three formaline tablets may be placed together with a small tube containing an antiseptic catheter paste suggested by Guyon and Frank.

Under no circumstances should the surgeon sanction the patient's carrying the catheter in his pocket or lining of his hat, as is frequently done. If the individual objects to employing the contrivance just described, he may use an inexpensive case made of German silver which is large enough to carry two catheters.

An ingenious apparatus for the sterilization of catheters by means of steam has been devised by Kuttner. In this apparatus the catheters are so arranged that the steam passes down through the instruments, emerges at the eye, then passes back outside and escapes at the upper end of the apparatus.

Filiform bougies which have been used should be washed with soap and water, dried, and sterilized in the same manner as the rubber instrument by the formalin process; or after thorough washing they may be immersed in a warm solution of the bichloride of mercury of a strength of 1 to 1,000, after which they should be rinsed in sterilized water and dried. These instruments if exposed to the air become hard and brittle and are destroyed by a parasite which attacks them. Consequently they should be preserved from contact with the air by either being kept in a metal case or by being wrapped in flannel smeared with mercurial ointment. Before using a metal instrument it should be examined to ascertain if it be smooth and polished. If any roughness or flaw can be detected it should be discarded.

Metal urethral instruments are readily sterilized by heat. After being used they should be thoroughly washed with hot water saturated with Johnston's ethereal soap (an admirable preparation, as the ether which it contains removes all the adherent fatty matter); they should then be boiled for ten minutes in a two-per-cent. solution of sodium carbonate, which prevents rusting; after which they should be either wrapped in sterilized gauze or placed in a rack made for the purpose. Before being again employed they should be placed in boiling water for five minutes, thoroughly dried on a sterilized towel, and dipped as far as the handle into a jar containing alcohol; after withdrawing the instrument, the adherent alcohol should be ignited. When the alcohol is consumed, the instrument is ready for use.

In cleansing the Gouley tunnelled catheter the same procedure is to be carried out; care being taken to observe whether the tunnel at the end of the instrument is clear and clean and whether the obturator works smoothly. This rule likewise applies to endoscopic tubes. Care should be taken to have the interior of the tube thoroughly dried after cleansing. This may be accomplished by passing a bit of absorbent cotton through the catheter. The most satisfactory mode of drying urethral instruments in order to prevent rusting is by placing them for a few minutes in a hot oven.

A very important matter connected with the use of urethral instruments relates to the question of the proper lubricant to be employed; it must be both aseptic and antiseptic. One of the best and by far the most satisfactory is petroleol (fluid cosmoline). It is a fixed oil from which all the volatile and offensive properties have been separated. It is not affected by climate and is not influenced by temperature; it contains no foreign ingredients. On exposure to the air it does not decompose nor turn rancid. Its reaction is neutral and it can be applied to the most sensitive urethra without producing irritation. It should be kept in a tall, wide-mouthed jar which can be tightly corked when not in use. It is easily rendered sterile by placing the jar containing the liquid in a sterilizer for a few minutes daily. I have used liquid cosmoline as a lubricant for many years with the most satisfactory results, and I can recommend it to the profession as one of the best of its class. The jar should be kept tightly corked and no instrument should be introduced into it until it has been sterilized. There is no lubricant that lessens the amount of friction as satisfactorily as oil. Guyon has suggested the use of a thick paste composed of:

℞ Pulv. saponis .... ℥ iv.
Acid. carbol..................... ʒ i.
Glycerini,
Aquæ ....āā ℥ iv.
M. Sig: Lubricant for urethral instruments.

Or—

℞ Pulv. saponis .... ℥ iv.
Resorcin .... ʒ iij.
Glycerini,
Aquæ ....āā ℥ iv.
M. Sig: Lubricant for urethral instruments.

These preparations have the advantage of being easily removed from the instrument. Unfortunately, in some cases their use is attended with a good deal of irritation. In the September number of the *Journal of Cutaneous and Genito-Urinary Diseases*, Dr. E. Wood Ruggles suggested a lubricant which I have found to be most efficacious. It contains:

℞ Gum tragacanth................ gr. xlviij.
Acid. carbol. (95-per-cent. sol.)... ♏i.
Glycerini .... ʒ iij.
Aquæ ....ad ℥ iv.

"Mix the three last constituents, pour the resulting liquid on the gum tragacanth in a mortar, and allow the compound to stand over night. Then triturate with pestle until a homogeneous mass is formed. It can then be used from an ordinary ointment jar or put into paint tubes if thought more desirable."

Bangs highly recommends a preparation which he has named "lubrichondrin"; it is especially useful in lubricating metal instruments protected by a rubber coat, such as the dilators of Oberlaender, and Kollmann, and the Otis' urethrometer. It consists of Irish moss (chondrus crispus) to which oil of eucalyptus (1 to 1,000) and formaldehyde (1 to 500) have been added. It is sold in closed tubes which may be boiled, thereby sterilizing the material before it is used. White and Martin have suggested a lubricant that I can also recommend. It is:

℞ Boroglyceride.................. ℥ iij.
Distilled water................. ℥ ix.
M. Sig: Use as lubricant for sounds.

It is not always necessary thoroughly to anoint metal instruments before they are inserted into the urethra. In many cases it will be found sufficient to lubricate well the meatus urinarius, by which means the instrument will be sufficiently lubricated to enable it to pass through the canal without difficulty. Should the slightest friction be experienced, the instrument should be at once removed and well anointed with whatever lubricant the surgeon may prefer.

The negligence of many physicians in permitting their patients to make use of rancid oil, lard, and even saliva for the lubrication of their urethral instruments cannot be too strongly condemned. When patients are taken to task for their carelessness they invariably reply that they were not aware of the danger they incurred, that their doctor had said nothing to them on the subject.

Patients who enter upon "catheter life" should always be warned of this danger, and of the pain and discomfort which may ensue from infection if proper cleanliness be not observed and if the instruments be not carefully sterilized. *Orville Horwitz.*

CATNIP.—*Cataria. Catmint.* The leaves and flowering tops of *Nepeta cataria* L. (fam. *Labiatæ*). This large and showy herb of Europe and Asia is very abundantly naturalized in the United States. It grows about deserted houses, barns, and in similar waste places. It becomes four or five feet high, and almost as broad, and, branching from the base, forms a pyramid of inflorescence, the flowers very small but very pretty. It is peculiarly aromatic and derives its name from the fondness of cats for it, which incites them to the most curious demonstrations. They not only eat it, but roll in it, and evince the utmost joy, and apparently affection, in its presence. Larger animals of the cat tribe, such as lions and tigers, act similarly, and great excitement may be caused at the "zoo" by introducing it into the cages. With a small amount of volatile oil and an amaroid, it is a very mild aromatic bitter. It is usually given in decoction, in large doses, the warm water aiding its diaphoretic action. *Henry H. Rusby.*

CATOOSA SPRINGS.—Catoosa County, Georgia.

POST-OFFICE.—Catoosa Springs. Hotel and cottages.

ACCESS.—From Atlanta and Chattanooga viâ the Western and Atlantic Railroad. Distance north from Atlanta, 115 miles; east from Chattanooga, 26 miles. From railroad, 2 miles.

This resort is nestled among the mountains of North Georgia at an elevation of 945 feet above the sea level. The aspect of the country is quite rugged, the Sandstone Mountain, about a mile distant, reaching an altitude of 1,800 feet above the tide water. From the summit of this mountain may be seen Mission Ridge, the historic Lookout Mountain, and many other points of lesser interest. The hotel and cottages at the springs have room for six hundred guests, and are supplied with all modern conveniences. The climate is bracing and invigorating, even in the summer months; in winter it is temperate, and the weather is not subject to sudden changes of temperature. The springs are fifty-two in number, situated within an area of two acres. It is not unusual to find quite different properties even among springs only a few feet apart. Most of them are quite strongly mineralized. The ten principal ones are as follows: The "All-healing," the "Red Sweet," the "Cosmetic," the "Chalybeate," the "Magnesia," the "Congress," the "Alum," the "Black Sulphur," the "White Sulphur," and the "Buffalo." They range in mineral ingredients from about 84 to 104 grains to the United States gallon. Following are analyses of three of the springs by Prof. W. J. Land, of Atlanta:

One United States gallon contains. Solids.	No. 4, or Chalybeate Spring. Grains.	No. 9, White Sulphur Spring. Grains.	No. 10, Buffalo Spring. Grains.
Calcium sulphate	41.56	44.81	45.00
Magnesium sulphate	27.90	32.01	33.02
Strontium sulphate	.20	.21	.29
Sodium sulphate	1.59	1.67	1.67
Potassium sulphate	2.30	2.32	2.31
Aluminum sulphate	.67	2.47	2.39
Calcium carbonate	3.75	3.85	3.86
Magnesium carbonate	7.48	8.40	8.70
Iron carbonate	.19	.28	.28
Lithium carbonate	Trace.	Trace.	Trace.
Manganese carbonate	.01	.02	.12
Strontium carbonate	.04	.04	.04
Potassium carbonate	.11	.11	6.01
Sodium carbonate	.26	.26	.03
Calcium nitrate	.37	.32	.03
Ammonium nitrate	.11	.10	.91
Calcium bromide	.26	.15	.15
Magnesium bromide	.30	.31	.33
Calcium fluoride	.02	.02	.01
Sodium chloride	.14	.14	.11
Crenic and apocrenic acids	.02	.01	.01
Free sulphuric acid	.01	6.13	.13
Free carbonic acid	4.31	4.51	4.62
Hydrosulphuric acid	....	.02	Trace.
Total ingredients	91.60	108.16	110.02

Total residue upon evaporation at 212° F. is 100.11.

All of these springs boil up through the hard black slate of the mountain side. They are perennial, the most severe and persistent droughts causing no perceptible difference in the rate of their flow. The waters are recommended for stomach, kidney, and bowel disorders, and for debility. The "All-healing" Spring is used for local troubles. The waters are shipped on order in bottles or barrels to any part of the country. *James K. Crook.*

CAULOPHYLLUM. See *Cohosh Blue.*

CAUSTICS.—Previous to the introduction of anæsthetics, caustics formed a very important part of the surgeon's armamentarium. The dread of the knife was but natural, and the sufferer eagerly seized upon any means that would render it unnecessary. At that period the advantage of the knife was not so marked as it is with modern aseptic surgery. After the use of this instrument gangrene and septic absorption were of very common occurrence, whilst the destructive action of caustics rendered the wound aseptic, and these undesirable complications rarely followed.

One of the principal uses of caustics was in the removal of gangrenous tissue from unhealthy wounds, whether traumatic or surgical. The unhealthy granulations and necrosed tissue were thus destroyed, and as the sloughs were detached a healthy healing surface appeared. Another important use was in the removal of tumors and new growths. If they were small, one or two applications would prove sufficient; if they were of great size, the growth would be destroyed in segments by the insertion of small pieces of caustic into its substance and then by removing the resulting slough. In certain instances a method adopted by M. Maisonneuve in 1858, known as *cautérization en flèches*, was followed. The idea was to surround the base of the tumor with small points of chloride of zinc which would separate the diseased tissue from the healthy as thoroughly as if a knife had been employed. The growth could then be enucleated and a healthy granulating surface would remain. Caustics were also of use in opening deep abscesses, as they slowly penetrated into the collection of pus and left a channel for its exit. For the treatment of sinuses and fistulæ, strands of thread were saturated with the caustic and drawn through the passages.

At the present day the usefulness of caustics is very limited, but when judiciously employed, there are several conditions in which they prove of much service. Their value is recognized as an application to the surface of unhealthy ulcers, as a means of destroying the poison in septic wounds, for the removal of small growths upon the surface and upon the mucous membrane of the oral, nasal, and vaginal cavities, and for the destruction of superficial malignant growths.

The treatment of indolent ulcers and other granulating surfaces with nitrate of silver, sulphate of copper, and other mild caustics is of daily occurrence and of unquestioned utility. The caustic coagulates the granulating surface, forming a thin covering which in a short time becomes detached, leaving a healthy surface. To destroy the poison of chancres, specific ulcers, wounds produced by venomous animals, and septic wounds, the stronger caustics are required. The part must be acted upon thoroughly and rapidly to prevent the absorption of the poison, and for this purpose fuming nitric acid, chloride of zinc, and chromic acid are some of the proper caustics to be selected. The destruction of warts, papillomata, etc., by the aid of caustics is common, and whether the frequent application of mild caustics is decided upon, or their rapid removal by the stronger caustics is adopted, the result is the removal of the growth with very little, if any, deformity. The employment of caustics in the treatment of malignant diseases of the skin is a question of much greater importance and one that has provoked much discussion; the surgeons adhering to the use of the knife, whilst the dermatologists hold strongly to the superiority of caustics. Those opposed to the use of caustics point out that they destroy only the localized disease and leave untouched the surrounding lymphatics and glands that may be infected; that an unsightly scar remains; and that the procedure is much more painful than when the part is excised and the wound made to heal by first intention. On the other hand, it is claimed that patients will submit earlier to the application of a paste, and that by these means the disease is really more thoroughly removed. It is thought that the inflammation excited in the surrounding parts will destroy the pathological cells that may exist, as their vitality is much lower than that of the normal cells, and when arsenic is used it is claimed by many that it exerts a special toxic action upon such cells. This action is not only exerted upon the structure of the tumor to which it is applied, but is thought to extend in all directions throughout the inflamed area and to exert a selective action upon the pathological tissue.

With modern surgical technique, there can be no question as to the advantage of the knife in the great majority of cases, but certain conditions arise in which the preference will be given to the treatment by caustics. In many cutaneous cancers, lupus, nævi, etc., especially such as are of slow growth and extend superficially rather than deeply, the employment of caustics will generally be more successful than excision. A consideration that counts in favor of the caustic, especially in the aged, is the avoidance of the necessity to administer an anæsthetic. The resulting scar is hardly to be considered, as, when the subcutaneous parts are not deeply involved, it is smooth and white, and not disfiguring.

Caustics should not be employed if any glands are involved, nor for any extensive disease upon mucous surfaces. They should be avoided when the skin approaches closely to the underlying bone, or over eminences. Upon the soft elastic tissue of the scrotum and similar tissues they must be used with great care, as the softness of the tissue renders it more difficult to control their action. Pain is not an objection to the use of caustics as it may be controlled by the admixture of morphine or by the application of cocaine to the part.

Caustics are difficult to manipulate successfully. To become proficient requires a great deal of experience, which is acquired only by the frequent and careful use of these agents. When applied they should be kept under observation and carefully removed when the proper degree of destruction has been secured. If they are left too long in contact with the parts there will be an unnecessary destruction of tissue; if for too short a time, the effect will be inadequate and often unfavorable, as the mild degree of inflammation excited by the caustic may add to the activity of the disease.

The after-treatment is that of ordinary surgical wounds. The necrosed tissue is not to be forcibly detached, but cut off in portions as it separates. If the destruction of the part is extensive, granulations should be favored, to reproduce as much tissue as possible; and, if it should be found necessary, the repair may be completed by skin-grafting.

Very many substances possess a caustic action, but experience has limited the number to a few which have proved most serviceable. Of these the principal ones are the corrosive acids, alkalies, arsenic, chloride of zinc, and chromic acid. Nitrate of silver is the type of the milder caustics, which are really little more than strong astringents. (For the actual cautery see article on *Cauterization.*)

ACIDS.—*Nitric acid* has proved the most serviceable of all the corrosive acids and is the one most employed. It acts rapidly, destroying the integument and the tissue beneath, the depth depending upon the quantity applied. Nitric acid is not so hygroscopic as sulphuric acid, but acts in a similar manner. It abstracts moisture from the tissues and combines with the albuminous constituents, producing a dry, yellow slough, which separates in about ten days, leaving a healthy granulating surface. It is not as painful as the alkalies or some of the less active caustics, on account of the rapidity of its action. One objection to its use is its tendency to diffuse itself on the surface. To overcome this the acid has been combined with saffron, asbestos, and sulphur to the consistence of a paste, which renders it more manageable. Its action may also be limited by covering the surrounding skin with gutta-percha or some greasy substance. Previous to the introduction of curetting, nitric acid was very extensively used as an intra-uterine application in various forms of endometritis. Curetting, however, has displaced the caustic and its use is now restricted to erosions and specific ulcerations. It is also employed with much success in all chancres, condylomata, etc. In the bites of rabid animals and poisonous insects and in septic wounds, its penetrating properties make it a very useful caustic. The acid is applied by means of a glass rod dipped into the acid, or of a small piece of cotton wool wrapped around the end of a probe or a splinter of wood. The part should be closely watched during the operation, and when it is sufficiently cauterized it should be washed with water or with an alkaline solution.

The Acid Nitrate of Mercury was a favorite caustic among French surgeons, but it is not much used at the present day. Its action is due to the nitric acid which it contains. In addition, the mercurial salt was supposed to supply an alterative effect. Its destructive power is not so great as that of the pure acid, and yet it is more liable to set up inflammatory action in the adjoining healthy tissues. It forms a dry, grayish-white eschar which falls off in from ten to twelve days. Its too free application has given rise to salivation.

Sulphuric Acid is the most powerful of the acid caustics and was formerly much employed. It has a very marked affinity for the water in the tissues, in consequence of which they are rapidly dehydrated. It destroys all the structures with which it comes in contact, and combines with the albumen and fibrin, forming a tough, structureless, black slough. This is very slowly detached and may remain adherent until cicatrization is complete. As with all fluid caustics it is extremely diffusible. This is lessened by mixing it with other substances to the consistence of a paste. Richard's paste was made with charcoal; Michel's consisted of asbestos, one part to three of acid. Syme used sawdust with the acid in equal parts.

Hydrochloric Acid has never been much employed as a caustic. It is milder than nitric or sulphuric acid and its slough is whitish and soft. Its local application in combination with its internal administration, in diphtheria, was advocated by Bretonneau.

Acetic Acid is a very mild caustic. It is chiefly employed in the treatment of warts, corns, and similar superficial growths. The pure glacial acetic acid only should be used, and care should be taken not to employ any that has been exposed to the air, as the acid rapidly absorbs moisture and is thereby reduced in strength.

Trichloracetic Acid is a very valuable caustic and one that will probably be more used in the future. Its advantages are, that it does not penetrate deeply and does not produce much inflammatory reaction. It has been particularly recommended in the treatment of nævi, and it is also used in venereal warts and in superficial cutaneous growths. A crystal is placed on the part to be cauterized and there is rapidly formed a dry, white, adherent eschar which is superficial, and leaves a very slight scar which is hardly noticeable.

Arsenous Acid.—This is the caustic most employed at the present day for the destruction of cancerous and other growths, when they are suitable for treatment by caustics. When applied to a raw or ulcerating surface, it produces an intense inflammatory reaction which terminates in gangrene and death of the part. The inflammation extends into the surrounding tissues, in all directions, lessening as it advances.

Arsenic does not exercise its caustic action upon the epidermis, and when the disease is not superficial it is necessary to remove the skin by curetting or by the application of an acid or an alkali. When required for use it is diluted to the extent of one half or two thirds with gum arabic and moistened to form a paste. There are a number of pastes which have acquired much celebrity. *Marsden's paste* was formed of 2 parts of arsenic with 1 of gum acacia. In *Dupuytren's paste* the arsenic was mixed with calomel in the proportion of 1 part to 10 or 15. *Esmarch's paste* consists of 1 part of arsenic, 1 part of morphine sulphate, 8 parts of calomel, and 48 of gum arabic. *Sir Astley Cooper's ointment* contains: Arsenic, 1 part; sulphur, 1 part; and spermaceti ointment, 8 parts. *The arsenical paste of Frère Cômo* contains 10 grains of arsenic, 2 scruples of red sulphite of mercury, and 10 grains of charcoal. *Plunket's caustic* contains: Ranunculus acris and ranunculus flammula, of each 1 ounce; arsenic, 1 drachm; and sulphur, 5 scruples—to be beaten together into a paste.

The length of time during which a paste is to be kept applied depends upon its strength. The extent of the cauterization may be estimated by the inflammatory areola in the surrounding tissues. This should not be allowed to advance too far, as a necrosis of the part will follow. On the other hand, if the redness is not well marked, the caustic action is deficient. When the arsenic is diluted one-half, the destruction of the part is likely to require from sixteen to eighteen hours; with Marsden's paste this will probably be accomplished in from ten to twelve hours. After the removal of the caustic the part is to be poulticed, and when the slough is detached, if the disease is not wholly removed, the application is to be repeated. The resulting scars are white and as a rule they are not disfiguring, unless the destruction of tissue has been great.

There is a possibility of poisoning from the absorption of arsenic, and as a precaution it is advised that not more than one square inch of surface should be covered at one time. The danger, however, is not very great, as the diseased surface is destroyed so rapidly that the poison is "walled off" from the absorbents and blood-vessels. Absorption really takes place more readily when a dilute solution is employed.

Recently it has been recommended that a solution of arsenic, in equal parts of alcohol and water, should be employed in preference to the pastes. The treatment is commenced with a solution of 1 to 150, and then the strength is increased to 1 to 80. The surface is prepared by washing and rubbing until the blood is made to appear; it is then allowed to dry and the solution is applied daily until the slough separates and the disease is destroyed. The treatment is continued for a period varying from one or two weeks to two or three months, according to the extent of the disease.

Chromic Acid.—Although slow in its action this is a very powerful and a very diffusive caustic. The pure crystals are employed or an aqueous solution of about one part in four. It produces great pain. When applied it immediately coagulates albumen, and, absorbing moisture, forms a fluid caustic, which dissolves the tissues. It gradually forms a dry, hard, dark eschar. It is particularly recommended in bites of venomous snakes, and is used to destroy superficial and mucous growths and syphilitic ulceration.

Carbolic Acid is also a mild caustic. It is not used to cause any destruction of tissue, but is employed in the treatment of poisoned wounds, syphilitic ulcerations, and hemorrhoids. It unites with albumen, producing a dry, white, and very superficial slough. It acts rapidly and painlessly, producing an anæsthesia of the spot.

ALKALIES.—The caustic alkalies have all been employed to a greater or less extent, but potash is the most active and has been most used. Their action differs from that of the acids in that they unite with the water of the tissues and, becoming fluid, destroy the underlying parts. They produce soft, gelatinous sloughs, which separate quickly and leave a slowly granulating surface. They penetrate deeply and, unless carefully applied, may cause much unnecessary destruction of tissue.

Potassa occurs as small, irregularly shaped masses, or in small cylindrical sticks, in which latter form it has been prepared for convenience of use. It is a very deliquescent salt and, unless carefully preserved, is difficult to use. The addition of lime lessens its affinity for water, and the official *Potassa cum Calce* is the most satisfactory preparation for caustic purposes. It is prepared by mixing equal parts of potassa and lime, and when moistened with a little alcohol this mixture forms the well-known *Vienna paste.* The mixture may also be fused and run into small cylindrical moulds. The greater the degree of heat employed the harder are the sticks. This caustic is kept applied to the parts for ten or fifteen minutes, and when the paste is used the area of its action may be limited by protecting the surrounding skin with adhesive plaster. The depth of cauterization depends upon the quantity of caustic applied and the length of time it is allowed to remain. When morphine is added in the proportion of one part to three it is said to form a painless caustic. Caustic potash and gutta-percha may be melted together in equal parts to form a paste which is very convenient for use, as it may be moulded into any shape.

Soda resembles caustic potash in appearance. It occurs in masses and in cylindrical sticks. Its caustic properties are milder than those of potash. It is not so deliquescent and possesses the advantage of being less diffusible. *London paste* is prepared by mixing together, in a warm mortar, equal parts of soda and unslacked lime, and moistening the mixture with water when it is wanted for use.

Sodium Ethylate.—This salt was introduced as a caustic in 1870 by Benjamin Ward Richardson. It is a white powder which, when brought in contact with moist tissue, is decomposed into alcohol and caustic soda. It is used as the Liq. Sodii Ethylatis which is official in the British Pharmacopœia. This is a solution of the salt in absolute alcohol. It is a syrupy, colorless liquid, and has been recommended as a very effective and manageable caustic. It is applied by means of a glass rod, for two or three successive days, and the resulting dry eschar should not be removed until it becomes detached. It has been successfully employed in the treatment of nævi, lupus, and superficial growths.

Zinc Chloride shares with arsenous acid the greatest popularity as a caustic in the treatment of cancerous ulceration. When applied to the surface, the skin is destroyed, but the pain is so severe that the corrosive acids are often applied first. When the zinc is then applied to the diseased tissue the pain is much less severe. Chloride of zinc acts rapidly, and, being deliquescent, it may—unless its action is controlled—effect a more extensive destruction of tissue than is desired. It coagulates the albuminous tissues and in a few hours forms a dry, firm, whitish slough, which separates in about one week. Chloride of zinc is mixed with wheat flour and formed into cakes, or with plaster of Paris, which very completely limits the extent of its action. Another method is to saturate lint with the deliquescent salt and then to cut off a portion of the required shape and size.

The chloride of zinc pastes are innumerable, as the fact that it has no toxic action has made it a favorite caustic with many. *Canquoin's pastes* are made in four strengths with wheat flour and water in the proportion of one part to two, three, four, or five parts of flour. *Mayet's paste* contains 8 parts of zinc chloride, 1 of zinc oxide, and 7 of flour; *Robiquet's*, equal parts of zinc chloride and flour, with gutta-percha added to form a firm mass. In *Landolphi's caustic*, the zinc chloride is combined with equal parts of chloride of gold, chloride of antimony, and chloride of bromine. What is known as *Bougard's paste*, which is being highly advocated, is composed of wheat flour, 60 gm.; starch, 60 gm.; arsenic, 1 gm.; cinnabar, 5 gm.; sal ammoniac, 5 gm.; corrosive sublimate, .50 cgm.; and solution of chloride of zinc at 52° C., 245 gm.

Silver Nitrate is a much weaker caustic than any of the foregoing. It has no effect upon the surface, but upon mucous membranes or denuded and granulating surfaces it causes a coagulation of albumen which results in a superficial slough. This is at first grayish white, but becomes dark owing to the reduction of the silver. It is dry and dense. This reagent acts rapidly, without pain, and does not excite any inflammatory action in the surrounding skin. It is used in the removal of warts, condylomata, etc., but is not of any service in the treatment of cancerous disease. It is chiefly employed in the management of unhealthy granulating surfaces, which it rapidly replaces with healthy healing granulations. The pure salt, fused into sticks for convenience of use, is generally employed. Some prefer the mitigated caustic, prepared by fusing the nitrate with two parts of nitrate of potassium. A very convenient method is to cover the end of a silver probe by fusing the nitrate and placing the probe in the liquid caustic, the adhering fluid being allowed to crystallize by exposure. For the destruction of chancres and syphilitic sores the nitrate of silver is not to be depended upon.

Other mild caustics which resemble the nitrate are sulphate of copper, sulphate of zinc, and sulphate of alumina.

Beaumont Small.

CAUTERIZATION.—The term cauterization is as correctly applied to the use of the potential cautery or caustic as to the actual cautery. The term, however, is so generally associated with the latter that it is almost restricted to the use of that form of cautery. Before the actual cautery was brought to its present state of perfection, it was much less employed than the caustics, but now their relative position is reversed and the actual cautery is the one generally employed. It is easy to apply, its action is more rapid, the heat is readily controlled, and the extent of cauterization may easily be defined. A great advantage of the actual cautery lies in the many devices to facilitate its use, as seen in the numerous burners or points, which range from the broad flat hammers to the finest needles, and include wire, scissors, knives, etc.

From the earliest days of medicine to the middle of the present century very little advance was made in the development of the actual cautery. The application of heated metals appears always to have been adopted, and the irons employed for this purpose remained much the same through all the centuries, and even at the present day they may be found in the possession of many. Such changes as were made were in the shape and number of the irons, or in the handles which were common to the several irons. A very crude method which retained its popularity until recent years was the application of heated coals, and the ignition of substances on the surface to be destroyed. The latter were known as *moxa* and were prepared by saturating cotton wool with nitrate of potassium and allowing it to dry; after which it was placed in a metallic tube with a handle, ignited, and allowed to burn down to the skin. With the introduction of illuminating gas, efforts were made to utilize it as a cautery, and instruments were made by which the jet of gas was brought in contact with the part to be cauterized.

In 1876 Paquelin introduced the thermo-cautery which bears his name, and it remains a favorite cautery on account of its portability and the ease with which it may be kept ready for use (Fig. 1196). The principles of this well-known appliance lie in the metal selected for the burners—these being made of platinum, a metal that becomes incandescent at a comparatively low temperature—and in the ingenious manner in which a light benzene gas is supplied to the heated point. As long as the gas is supplied the point remains heated, the degree of heat depending upon the quantity of gas, which is easily controlled by the india-rubber bulb (Fig. 1197). Many other cauteries, based upon the same principle, have been made, but none has hitherto supplanted that of Paquelin. The electrical cautery, however, is destined to be the cautery of the future, its advantages being very marked, especial-

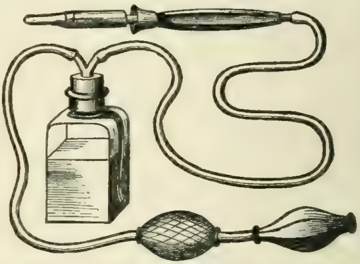

Fig 1196.—Paquelin's Thermo-Cautery Ready for Use. It consists of bulbs of Richardson's spray apparatus, a glass receptacle for fluid, and a movable platinum burner in a non-conducting wooden handle.

ly in surgery of the cavities of the nose and throat. The electricity is supplied by wet or dry cell batteries, or may be drawn directly from the domestic supply with the intervention of a transformer. The expensiveness of these instruments has been an obstacle to their general use, but this is now no longer a fact, and excellent galvano-cauteries are within the reach of all.

There is a marked difference between the burners of the thermo-cauteries and those of the galvano-cauteries. As a current of electricity requires to pass through the burners of the latter, they are either in the form of a wire loop, or are formed of porcelain around which the wire is wound. In the latter forms the porcelain readily becomes incandescent when the current is passed through the wire. The ease with which the point can be heated or cooled is a great advantage of the galvano-cauteries. Thus, for example, the burners may be placed in position before being heated and not removed until they become cool.

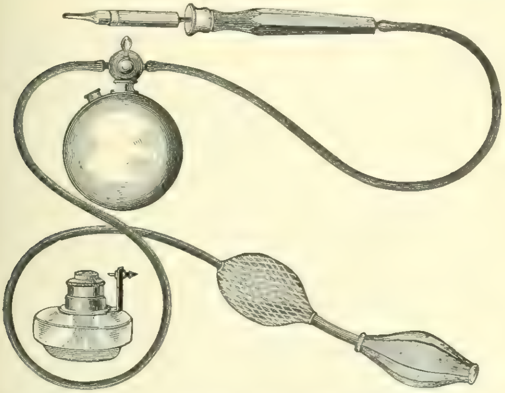

FIG. 1197. Modification of Paquelin's Thermo-Cautery. A metallic vessel lined with sponge receives the benzene, and is provided with a stopcock to control the insufflation.

Three degrees of heat are found desirable in the use of the actual cautery: a white heat, a red heat, and one in which the metal has not become candescent. The white heat is the most intense and the most destructive of tissue. It is also the least painful, as the terminals of the nerves are destroyed too rapidly to allow them to convey the impression of pain. The black heat is not used for cauterizing purposes, but almost solely for that of counter-irritation. As a hæmostatic red heat is superior to white.

The depth and extent of tissue destroyed depend upon the degree of heat and the length of time during which it is applied. It chars and destroys all tissues, and leaves a thin, dry, hard eschar, which does not become detached for several days. Ordinary hemorrhage is immediately controlled, but in the removal of pedunculated tumors, when the supplying vessels are large, it should not be depended upon. The actual cautery is employed for the removal of small tumors, hemorrhoids, and superfluous hairs, in the destruction of cancerous and unhealthy surfaces, in poisoned wounds, and in all conditions in which a caustic is desired. In the treatment of affections of the nose and throat, and in gynæcological work, it is of particular service.

As a hæmostatic, the actual cautery has always been of much service. In former times it was the principal means of controlling hemorrhage, and at the present day all operating rooms are provided with a cautery to check the bleeding from vascular tissues and from oozing surfaces.

As a counter-irritant the actual cautery has occupied a foremost position and has proved of much service. (See also *Caustics* and *Counter-Irritation.*)

Beaumont Small.

CEANOTHUS.—*New Jersey Tea. Redroot.* The root of *Ceanothus Americanus* L. (fam. *Rhamnaceæ*), a low, much and densely branched shrub of Eastern and Central North America, represented in the far West by numerous other species with the same properties. Its fruits much resemble those of the tea plant, which fact is said to have led to the use of its leaves as a substitute for tea during the revolutionary embargo. The root has enjoyed domestic and a slight professional use as an astringent. It is stout, much and crookedly branched, of a bright reddish color, which soon fades on keeping, hard and woody. The red color pervades the wood. It contains six to nine per cent. of tannin, the bark containing more than the wood. The leaves contain an equal amount. One-fifth per cent. of *ceanothine*, an alkaloid, has been reported, but nothing is known of its properties. Owing to the close resemblance, in appearance and properties, of this root to Peruvian rhatany, it has been used as a substitute and adulterant of the latter.

The dose of ceanothus is 4 gm. (ʒ i).

Henry H. Rusby.

CEDAR KEYS.—A small town of about 2,000 inhabitants, situated upon the gulf side of Florida, 155 miles southwest from Fernandina, with which it is connected by railroad. As will be seen from the accompanying climatic chart, the climate is a mild, equable marine one, with a large number of clear and fair days:

CLIMATE OF CEDAR KEYS, FLA. LATITUDE, 29.8; LONGITUDE, 83.2; PERIOD OF OBSERVATION, FOUR YEARS.

Data.	December.	January.	February.	March.	Year.
Temperature (Fahr.)—					
Average or normal	59.5°	59.8°	62.0°	63.9°	71.3°
Average daily range	12.1	12.1	12.2	12.5	
Mean of warmest	65.6	64.4	68.8	71	
Mean of coldest	53.5	52.3	56.6	58.5	
Highest or maximum	78	77	79	82	
Lowest or minimum	22	32	35	40	
Humidity—					
Average relative	80.8%	81%	75.4%	71.5%	75.4%
Precipitation—					
Average rainfall in inches	2.73	5.31	2.98	3.58	58.02
Wind					
Prevailing direction	N.E.	N.E.	N.E.	S.W.	N.E.
Average hourly velocity in miles	8.5	9	9.6	11.1	9.2
Weather—					
Average number of clear days	14	8.5	13.8	14	158.4
Average number of fair days	11.4	14.7	9.2	12.2	149.4
Average number of clear and fair days	25.4	23.2	23	26.2	307.8

The winter climate is said to be milder than that found upon the east, or Atlantic, coast of Florida. The facilities for bathing, boating, fishing, and hunting are also said to be good. So far as climatic conditions are concerned, Cedar Keys differs but little from Tampa, about 100 miles farther south on the same coast, but the former has not become a "resort" like the latter, and has no such accommodations as exist at Tampa. The drainage and water supply are also said to be questionable. Although Cedar Keys is reputed to be "extremely healthful," one would hardly care to send an invalid there unless he were sure of obtaining adequate accommodations and favorable hygienic conditions. These latter are quite as essential as a favorable climate in the selection of a health resort. *Edward O. Otis.*

CEDAR SPRINGS.—Preble County, Ohio.

Post-Office.—New Paris. Hotel.

Access.—Take Pittsburg, Cincinnati, and St. Louis Railroad to New Paris, 35 miles west from Dayton; thence take carriage one mile to springs.

These springs are situated in a rolling section of country, about 1,000 feet above the sea level. The surroundings are very pleasant and attractive. There are said to be not less than one hundred springs within an area of two square miles. Several are used for medicinal purposes. We present an analysis of one of them by Dr. A. Fennel:

Washington Spring.

One United States Gallon Contains:

Solids.	Grains.
Sodium carbonate	2.26
Magnesium carbonate	5.82
Iron carbonate	1.32
Calcium carbonate	3.96
Calcium sulphate	1.24
Sodium sulphate	.18
Calcium phosphate	2.13
Sodium chloride	.98
Alumina	.22
Total	18.11

The waters resemble those of the Bethesda Spring at Waukesha, Wis., but contain more iron. It is claimed that they are especially valuable in catarrh of the bladder, in renal diseases, and in dyspepsia.

James K. Crook.

CEDRON SEEDS.—The seeds of *Simaba Cedron* (R. Br.) Planch. (fam. *Simarubaceæ*). The plant is a small tree of Northern South America, and is considerably cultivated in the tropics. It yields an edible fruit about the size of, and somewhat resembling, a large peach. The solitary seed is similar to a Brazil nut in both form and size. In their home, the seeds have a high repute as an antiperiodic, and trials with them here have largely supported these claims. Their use as an alternative of the cinchona products appears well justified. The white or whitish crystalline volatile amaroid *cedrin* appears to be the active constituent, though the presence of an alkaloid has been claimed. Cedrin is soluble in both water and alcohol. Cedron seed is commonly given in the form of the fluid extract, the dose of which is .06 to .5 c.c. (♏i. to viij.). *Henry H. Rusby.*

CELANDINE. CHELIDONIUM.—"The entire plant, *Chelidonium majus* L. (fam. *Papaveraceæ*)" (U. S. P.). In some pharmacopœias the root only has been recognized, but the composition and properties are the same throughout. The drug is little used and will probably be dropped from the Pharmacopœia at its next revision. This, the only species of the genus, is a perennial herb, with slender branching stem, bright yellow delicate flowers, and an acrid, irritating, disagreeable-smelling yellow juice. The plant is sufficiently described by the Pharmacopœia in its description of the dried herb. "Root several-headed, branching, red-brown; stem about twenty inches (50 cm.) long, light green, hairy; leaves about six inches (15 cm.) long, petiolate, the upper ones smaller and sessile, light green, on the lower side glaucous, lyrate-pinnatifid, the pinnæ ovate-oblong, obtuse, coarsely crenate or incised and the terminal one often three-lobed; flowers in small, long-peduncled umbels with two sepals and four yellow petals. Capsule linear, two-valved and many-seeded. The fresh plant contains a saffron-colored milk-juice and has an unpleasant odor and acrid taste."

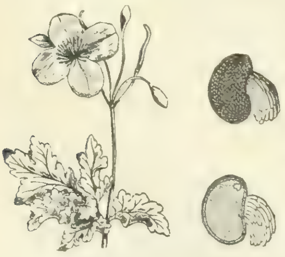
Fig. 1198.—Celandine, Slightly Reduced. Seed enlarged about four times. (Baillon.)

Celandine is a native of Europe, but has been abundantly naturalized in the United States, where it affects rich, shaded dooryards. It is an old country medicine, and has been used to dissipate warts and as a dressing for ulcers. Its general composition is very similar to that of bloodroot, but the important alkaloid is *chelerythrine*, associated with *chelidonine*, *a* and *β homochelidonines* and *protopine*. There are also *chelidonic* and *chelidoninic acids*. Chelerythrine acts in a markedly different way from its close relative, sanguinarine, lacking entirely the irritating properties of the latter upon the motor centres, which it depresses or paralyzes from the first. It also depresses the muscles. The ends of the sensory nerves are first irritated and then depressed. Chelidonine tends to counteract this primary sensory stimulation. The homochelidonines and protopine are in very small amounts. Their effects are also in the general direction of both sensory and motor depression. Hence the effects of celandine are not violently irritating like those of bloodroot, and are finally soothing and depressing. There is, however, enough sanguinarine, in connection with the primary sensory irritation of the chelerythrine, to make the drug strongly irritating in the first stage of action. It acts as a laxative or a purgative, and has always been regarded as an active cholagogue. Large doses may cause emesis, but the tendency of this drug is purgative, as that of sanguinarine is emetic. There is no official preparation. The dose is 1 to 4 gm. (gr. xv. to lx.). The extract is mostly used, in doses of .5 to 1 gm. (gr. viij. to xv.). The drug has been a favorite domestic basis for poultices, and the juice is a counter-irritant, similar to bloodroot.

Henry H. Rusby.

CELASTRUS. See *Bittersweet, False Climbing.*

CELERY.—This well-known succulent vegetable, *Apium graveolens* L. (fam. *Umbelliferæ*), is distilled in the fresh state for a delicious volatile oil which is used for flavoring. The fruit, however, is the important part from the standpoint of materia medica. It is similar to the other cremocarps of the family, but is very small, only one-twenty-fifth inch in length, broadly ovate, dark brown, hard, smooth, and generally contains twelve oil tubes. It is largely used in its own form for flavoring purposes and as a carminative, similarly to its relatives, and in doses of grams ij. to iv. (ʒ ss. to i.). Its volatile oil, containing limonene, is also largely used for the same purposes. *Henry H. Rusby.*

CELL.—A cell is one of the elementary forms of organized substances of animals and plants. It is irreducible into more simple parts except by mechanical or chemical means; it is therefore the *histological element.*

Historical.—It is to the botanists that the credit of the discovery of the minute structure of living matter is due. At the end of the seventeenth century Malpighi and Grew demonstrated the fact that plant tissue was made up of small spaces with firm walls, and that these spaces were filled with fluid. They called these spaces cells, from the Latin "cella," a little cavity or space. Further investigation showed that this plant cell contained, in addition to the fluid, a somewhat granular substance and that this granular mass contained a darker spot, which spot we now know to be the nucleus.

Investigation of animal tissue by Purkinje, Valentin, Müller, and Henle (1830–40) showed that it was composed of elements similar to those of plant tissue. In 1838 Schwann, as the result of his investigations, announced the fact that animal and plant tissues were made up of similar elements, and he defined these elements, the cells, as "small vesicles, with firm walls, enclosing fluid contents."

As the investigation of the plant cell advanced it was found that in many instances it was completely filled by this granular substance, and it was named protoplasm by Mohl. Further investigation of the animal cell showed that the cell wall was absent in many cases, and the question was raised as to whether these bodies could be classified as cells. It was also found that these bodies were identical in structure with the protoplasm of Mohl, and the term protoplasmic bodies was applied to them by Remak.

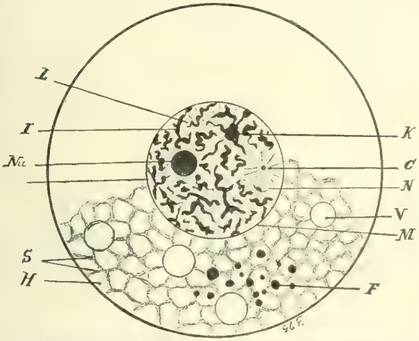

Fig. 1199.—Diagram of a Cell. *C*, Centrosome; *F*, foreign body; *H*, hyaloplasm; *I*, intranuclear network or reticulum; *K*, karyosome or false nucleolus; *L*, linin; *M*, nuclear membrane; *N*, nucleus; *Nu*, nucleolus; *S*, spongioplasm; *V*, vacuole.

In 1860 Max Schultze announced his protoplasmic theory of the structure of animal cells. He demonstrated that the cell wall or membrane of the earlier investigators was not an essential part of either the animal or the plant cell; that, as a general rule, the plant protoplasm had a firm wall, but under certain conditions it became divested of it and then assumed the same characteristics as those of the animal protoplasm. Having determined that the element was not a cell or little space filled with fluid, but a formed material, he still retained the term cell of the earlier investigators. We still continue to use the same term, as it has become a fixture in biological nomenclature. Schultze defined a cell "as a little mass of protoplasm endowed with the attributes of life."

As the investigation of the cell proceeded it was found that this mass of protoplasm was of a much more intricate structure than was at first supposed, and that the dark spot, the nucleus, was an important part. This necessitated a revision of Max Schultze's definition, and the following was formulated: "A cell is a little mass of protoplasm, which contains in its interior a specially formed portion, the nucleus."

During the last decade a vast amount of information in regard to the structure of the cell has accumulated. This is especially so in regard to the nucleus and the part it plays in the process of cell division. These discoveries will be considered in the discussion of the structure of the cell.

STRUCTURE OF THE CELL.

1. Cell body, Protoplasm, or Cytoplasm,
    - *a.* Spongioplasm or cytoreticulum,
    - *b.* Hyaloplasm,
    - *c.* Microsomes.
2. Nucleus, or Karyoplasm.
    - *a.* Nuclear membrane,
    - *b.* Intranuclear network,
        - *a.* Chromatin.
        - *b.* Linin.
    - *c.* Karyolymph or nuclear sap,
    - *d.* Nucleoli.
3. Centrosome.
4. Cell membrane.

Cytoplasm (cell body, protoplasm).—Under the ordinary powers of the microscope the cytoplasm has a granular, in some instances a homogeneous appearance; but upon analysis with the highest powers it is found to be composed of two distinct substances: the *spongioplasm* or *cytoreticulum* (Fig. 1199, *S*), which forms a network or reticulum the spaces of which are filled with what is believed to be a fluid substance, and the *hyaloplasm* (Fig. 1199, *H*). The proportion of these two elements varies. In young cells the hyaloplasm predominates, but as the cells grow it decreases relatively, and the spongioplasm increases. The amount of the spongioplasm, the thickness of its threads, and the size of its meshes also vary in different cells. Embedded in the cytoplasm are minute granules, the *microsomes;* these, together with the nodal points of the spongioplasm, give the granular appearance to the cell-body. The distribution of the microsomes is not uniform; usually the periphery of the cell is entirely free from them, and then in some cells they are grouped in masses or they may be distributed irregularly. If they are numerous and coarse in character, the cytoplasm has a dark look; if they are fine and less numerous it has a lighter or nearly clear appearance. In addition to the microsomes other objects are sometimes found in the cytoplasm, viz., pigment or fat granules and clear, spherical-shaped cavities—*vacuoles* (Fig. 1199, *V*).

In 1892 Butschli published the results of his observations on the minute structure of cytoplasm. He claimed that the reticular appearance was due to the fact that it was a *foam* or *emulsion*, being made up of numerous microscopic vacuoles, the walls of which were in close apposition, so that the microscope showed them only in optical section and not their surfaces. In order to confirm this theory he made numerous experiments and finally succeeded in producing what he called "artificial cytoplasm," which when viewed with the microscope had nearly the same appearance as the spongioplasm of a cell. This artificial cytoplasm was made by rubbing up olive oil with cane sugar or potassium hydrate. A drop of this mixture was placed on a slide, a small drop of water was added, and the whole was covered with a cover glass, the weight of which spread it out in a thin layer. From these experiments he concluded that cytoplasm was a mixture of fluids of different densities, the heavier forming the walls of the vacuoles, while the lighter collected in their cavities.

At present we have two theories as to the structure of cytoplasm: the *reticular*, which is supported by the majority of investigators, and the *foam* or *emulsion* theory, which is advocated by Butschli and his school.

Nucleus.—The *nucleus* or *karyoplasm* (Fig. 1199, *N*) is now known to be the important part of the cell, being the centre of all its activity. It is generally embedded in the cytoplasm, but in a few cells it projects above the surface. It stains, or, more properly speaking, some of its elements stain, with certain dyes, such as carmine, hæmatoxylin, etc.

It may be spherical, oval, rod-like, or irregular in its shape, and its size is generally in proportion to the size of the cell. In a few instances it is nearly as large as the cell itself (lymphocytes). Every cell, as a rule, has at least one nucleus, sometimes two or more, and in the large giant cells one hundred or more have been found. A few cells—red blood cells, the surface cells of the epidermis, and the respiratory cells of the terminal air passages of the lungs—are without nuclei.

These cells did at some previous time have a nucleus, but in the process of differentiation the nucleus disappeared.

In the resting state the nucleus is surrounded by a membrane, the *nuclear membrane* (Fig. 1199, *M*), which encloses the nuclear contents or *karyoplasm.* This membrane is divided into two layers, an inner or *chromatic*, and an outer or *achromatic.* By some investigators it is considered as a special condensation of the cytoreticulum. The karyoplasm is made up of a formed material, the *intranuclear network* or *reticulum* (Fig. 1199, *I*), and of what is believed to be a fluid substance, the *karyolymph* or *nuclear sap*, which fills the spaces formed by the reticulum. The intranuclear network is composed of two elements: *chromatin*, which stains with the nuclear dyes, and *linin* (Fig. 1199, *L*), which does not stain. The chromatin occurs in the form of irregular anastomosing threads, which are supported by the linin. These chromatin threads vary in their thickness and arrangement. In some nuclei they appear in the form of a thick or thin convoluted thread; in others as rounded or irregularly shaped granules. Some investigators believe that the chromatin occurs in the form of short, rod-like masses and that these masses are embedded in the linin. The linin is a transparent, unstainable substance, only to be demonstrated by special methods of preparation.

The *Nucleoli* are of two kinds: the true nucleoli or *plasmosomes* (Fig. 1199, *Nu*), and the net knots or *karyosomes* (Fig. 1199, *K*). The true nucleoli are spherical in shape and they stain intensely with the nuclear dyes. They may lie free in the nuclear sap or they may be attached to the threads of the intranuclear network. The karyosomes or false nucleoli are thickened nodal points of the reticulum. The function of the true nucleoli is unknown.

Centrosome.—This is a minute spherical-shaped body (Fig. 1199, *C*) found within the nucleus in the resting state. It is the special organ controlling the process of cell division. In the earlier stages of this process it passes into the cytoplasm, remaining near the nucleus, and is surrounded by a zone of fine, radiating fibrils, the *attraction sphere* or *archoplasm*. In some few cells no centrosome has been discovered as yet, but this is believed to be on account of its minute size and difficulty of demonstration.

Cell Membrane.—The cell membrane is now believed to be an unimportant part of the animal cell. It is present in but a few instances—fat cells and the ovum being exceptions. In the ovum it is well developed and has structural differences; in other cells, however, it is generally of a homogeneous appearance and is considered by many to be a condensation of the cytoplasm.

Cells differ greatly in shape. They may be oval or spherical—the form of all young cells; discoid, as in the case of the red blood cells; flat, as in some forms of epithelium; cylindrical or columnar, as in the epithelium of the intestine; or, finally, irregular, as in the connective-tissue cells and nerve cells. The element of pressure is an important factor in the modification of the shape of cells, and is well exemplified in the various forms of stratified epithelium.

VITAL PROPERTIES OF CELLS.—Under this heading are grouped the phenomena of *movement, irritability, metabolism,* and *reproduction.*

Cells exhibit the phenomena of movement under three forms: *protoplasmic, amœboid,* and *ciliary.*

Protoplasmic movement is difficult of observation on account of the slowness of the process. It has been demonstrated in a few animal cells, and in plant cells it is easily observed, the streaming of the cytoplasm being an example. All animal cells are believed to possess it to a greater or less degree. It is made manifest by the changes in the form of the cytoplasm, by the movements of the microsomes, and by the changes in the position of the nucleus.

Amœboid movement is similar to that exhibited by the unicellular organism, the amœba. Nearly all animal cells possess it to some extent, it being well marked in a special few, viz., the leucocytes, lymph cells, and wandering connective-tissue cells. If a living leucocyte be studied under the microscope, it will be seen to change continually its form (Fig. 1200). Gradually a bud-like mass of the cytoplasm will push out from some point, or several may start from different points. These *pseudopodia* may retract, or one may be extended for a considerable distance, the remainder of the cytoplasm flowing into it. Other pseudopodia are given off and the above process is repeated. By this means the cell will gradually crawl through the field of the microscope. It is by means of this amœboid movement that the leucocytes pass through the walls of the capillaries and wander through the spaces of the tissues and organs or between other cells.

Ciliary movement is the power possessed by the hair-like appendages of certain cells (see *Epithelium*).

Irritability is the property that cells have of responding to external stimuli. These stimuli, though almost innumerable, may, in a general manner, be grouped as mechanical, electrical, and chemical in their nature, or as due to heat and light.

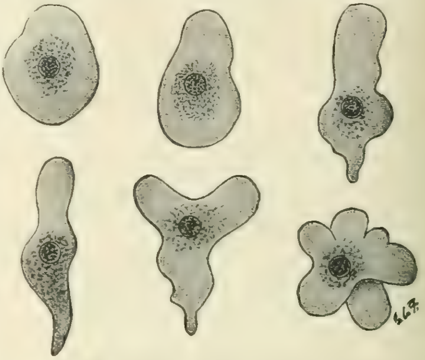
FIG. 1200.—Amœboid Movement. (After Verworn.)

All cells do not react in the same manner to the same stimulus, nor do all stimuli cause the same reaction in an individual cell. The response of a cell to a specific stimulus depends upon its structure. Some, those of the organs of vision, for example, respond to light only; while others may respond to one or more stimuli.

Under mechanical stimuli are classed pressure, violent shaking, and crushing, any one of which causes cells to react in some manner.

While heat is a necessary condition for the vital activity of cells, it must be confined within rather fixed limits; these varying considerably, however, for different cells. If the temperature be raised to 40° C. the vitality of the cell is destroyed, but, on the other hand, the temperature may be lowered to a considerable extent without the cell being killed. An increase of heat above that at which a cell normally exists causes a marked increase in its vital processes, until the heat-rigor point (40° C.) is reached, when a coagulation takes place and the cell is killed. Lowering of the temperature below the normal produces a gradual diminution of activity until the cold-rigor (0° C.) point is reached, when the cell passes into a "narcotic" state. Apparently cells can remain in this state for a considerable length of time without their vitality being destroyed, for if they be gradually warmed up to their normal temperature their vital functions are resumed.

Light, in the higher order of animals, is believed to be a stimulus to the cells of the organs of vision only. In some of the lower animals, other tissue cells, especially those of the skin, respond to its stimulation.

Electrical stimuli, when applied in the form of weak currents, cause an increase, strong currents a decrease, in cell activity. If the latter are continued for a considerable length of time they cause the death of the cell.

Chemical stimuli are almost numberless, and at present their manner of action is not thoroughly understood. Some cause contraction, some increased movement, others increased secretive activity, etc. A striking example of the effect of chemical stimuli is that known as *chemotaxis*. This is the property possessed by certain cells of responding to the stimulation of chemical substances introduced into or formed in the body. Some substances cause the cells to approach them—*positive chemotaxis*; others repel them—*negative chemotaxis*. The leucocytes respond quickly to this form of stimulation.

Metabolism is the property which cells possess of absorbing and of giving off materials. The former process is termed constructive metabolism or *anabolism*, the latter destructive metabolism or *katabolism*. The anabolic products are retained in part by the cell for its nutrition and the remainder are given off as its specific secretion. Katabolic products are mostly thrown off as excretions.

Reproduction.—All of the multitude of cells entering into the formation of the various tissues and organs of the adult animal body are derived from one original cell, the ovum. Every cell is the result of the division of a preexisting cell (mother cell) into two cells (daughter cells). This process is known as *cell division*.

Two chief forms of cell division are now recognized: indirect cell division (*karyokinesis*, *karyomitosis*, or *mitosis*) and direct cell division (*amitosis*).

Indirect cell division, or mitosis, is the process by which the vast majority of the cells of the animal body divide. In this form of division the intranuclear network undergoes a series of complicated changes; the nucleus divides, and finally the cell body itself, into two equal portions.

The process is divided into four stages: the first

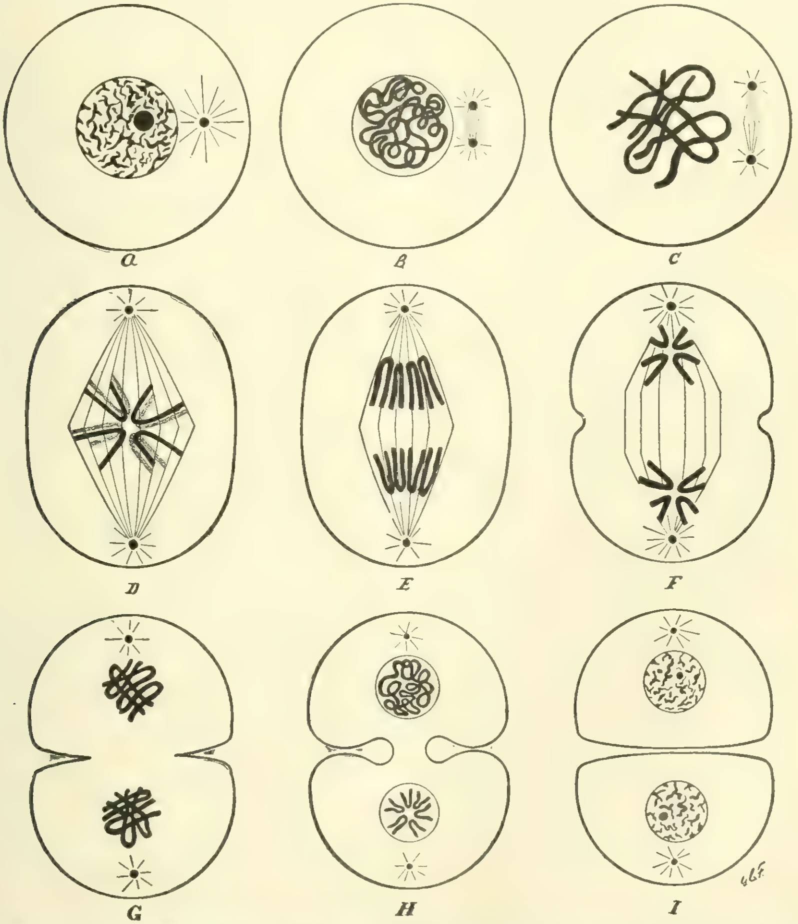

FIG. 1201.—Diagram of Indirect Cell Division or Mitosis. (After Böhm and von Davidoff.) *A*, Cell with resting nucleus; *B*, prophases; nucleus showing thickened convoluted thread of chromatin, daughter centrosomes, and early stage of the formation of the achromatic spindle; *C*, prophases, formation of the chromosomes; *D*, prophases, achromatic spindle in long axis of the nucleus, chromosomes dividing; *E*, anaphases, chromosomes moving toward the centrosomes; *F*, anaphases, chromosomes collected at the poles of the nucleus forming the diaster; commencing constriction of the cell body; *G*, telophases, further constriction of the cell body, daughter nuclei returning to the resting state; *H*, telophases, deeper constriction of the cell body, daughter nuclei showing monaster and convoluted thread of chromatin; *I*, telophases, complete division of the cell body forming daughter cells the nuclei of which have returned to the resting state.

stage, *prophases*, in which the nucleus undergoes a series of preparatory changes; the second stage, *metaphases*, in which the first steps in the division of the nucleus take place; the third stage, *anaphases*, in which the nuclear material is distributed to the new-forming nuclei; finally the fourth stage, *telophases*, in which the complete division of the nucleus and cell body takes place, with the formation of daughter cells.

Prophases.—The resting nucleus enlarges and the centrosome passes into the cytoplasm, where it divides in such a manner as to form daughter centrosomes. The daughter centrosomes lie near the nucleus, separated by quite an interval, each being surrounded by the radiating fibrils of the *archoplasm*, some fibrils of which, stretching between the centrosomes, form the *achromatic spindle* (Fig. 1201, *B*). The intranuclear network becomes converted into a fine convoluted thread, which in some cases is continuous; in others it is broken up into several threads. The thread or threads next shorten and become thicker, the convolutions being reduced in number. At this stage the chromatin stains intensely and resists the action of decolorizing agents. The chromatin next becomes arranged in a series of connecting loops, forming the *wreath*. The nuclear membrane and the nucleolus disappear. In some cases it appears that the nucleolus is thrown out into the cytoplasm and there degenerates. The wreath breaks up into V-shaped segments, the *chromosomes* (Fig. 1201, *C*). These chromosomes are always of an equal number, varying from two to thirty-six, and each species of animal has a characteristic number, which in man is sixteen.

The centrosomes migrate to the poles of the nucleus, and the achromatic spindle appears in its long axis, being formed by some of the fibrils of the archoplasm stretching between them (Fig. 1201, *D*). The chromosomes, which have become much shorter and thicker, collect around the axis of the nucleus at its equator, the *equatorial plane*, their closed ends being directed toward the centre, forming the *monaster* (Fig. 1201, *D*).

Metaphases.—This stage is the commencement of the actual division of the nucleus. The chromosomes of the monaster split lengthwise into halves, which at first lie close together, but gradually draw away from each other (Fig. 1201, *D*) and form daughter chromosomes, the original chromatin being divided into equal portions.

Anaphases.—The nuclear material is, in this stage, equally distributed to the now forming daughter nuclei. The chromosomes separate into two equal groups, and each group gradually moves toward one of the centrosomes (Fig. 1201, *E*), where they collect in a form similar to that of the monaster; this is termed the *diaster* (Fig. 1201, *F*). Toward the close of this stage the cytoplasm becomes slightly constricted at the equatorial plane.

Telophases.—The constriction of the cytoplasm noticed in the previous stage continues to deepen until the cell-body is divided into equal halves, forming daughter cells, each of which receives one of the groups of chromosomes, one-half of the remaining nuclear material, and one centrosome. The nuclear membrane and the nucleolus reappear and the daughter nuclei return to the resting state (Fig. 1201, *G*, *H*, *I*).

Direct Cell Division or Amitosis.—This form of cell division is now believed to be confined to the lymph cells and leucocytes. The nucleus in this form of cell division divides without the intranuclear network undergoing the same complicated changes as in the indirect form.

The nucleus first becomes constricted (Fig. 1202, *A*); this constriction gradually increases and finally cuts the nucleus into two parts, forming daughter nuclei; these daughter nuclei draw away from each other by amœboid movement (Fig. 1202, *B*). At times the complete division is delayed and the nuclei remain connected, for some time, by a narrow thread of the nuclear material (Fig. 1202, *C*). Division of the cytoplasm take splace by the development, at first, of a constriction between the nuclei, and then finally by the entire separation of the daughter cells thus formed. Like the nucleus, the cytoplasm may in some instances remain connected (Fig. 1202, *D*), or its division may be delayed while the nuclei go on dividing, the result being an accumulation of nuclei and the formation of multinucleated cells.

The innumerable cells found in the adult organism, though derived from a common parent, the ovum, lose in many respects all resemblance to that cell. They assume new forms and functions, these being brought about by a process of cell differentiation.

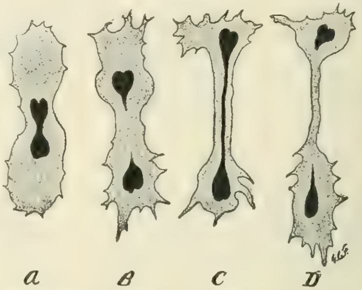

FIG. 1202. Direct Cell Division or Amitosis. (After Arnold.) *A*, Constriction of the nucleus; *B*, complete division of the nucleus, commencing constriction of the cell body; *C*, daughter nuclei still connected by a thread of nuclear material; *D*, daughter cells still connected by a narrow band of cytoplasm.

After the fertilization of the ovum it divides by mitosis and at first the daughter cells resemble the mother cells. Soon changes make their appearance in the cells and they can be grouped into two forms. These two forms continue to multiply and finally they become arranged into three distinct layers—*the layers of the blastoderm*. From these layers of the blastoderm all of the tissues of the body are derived, each layer furnishing certain specific tissues.

For more minute details of the structure and function of cells consult "The Cell in Development and Inheritance," E. B. Wilson, and "General Physiology," Max Verworn, translated from the German by Frederic S. Lee, M.D. *George C. Freeborn.*

CENTAURY, AMERICAN. See *Gentianaceæ.*

CEPHAELINE. See *Ipecac.*

CEPHALHÆMATOMA.—The name given by Naegele is from the Greek, *κεφαλή*, the head, *αιμα*, blood, and *ωμα*, morbid condition. A morbid condition of the head characterized by an effusion of blood. Latin *Cranii tumor sanguineus;* French, *Céphalématome*, or *Tumeur sanguine de la tête;* Italian, *Cefalhæmatoma;* German, *Kephalämatom*, or *Kopfblutgeschwulst*. First described by Michaelis.

SYNONYMS.—Cephalæmatoma; ecchymoma capitis; ecchymoma capitis recens natorum; thrombus neonatorum; abscessus capitis sanguineus neonatorum; tumor capitis sanguineus neonatorum; cephalophyma; craniohæmatoncus.

DEFINITION.—An effusion of blood upon or within the crania of newly born infants.

VARIETIES.—Subaponeurotic, the simplest, but not the most common form—a bloody effusion immediately underneath the cranial muscles.

Subpericranial, situated between the pericranium and cranial bone—the most common form.

Diploic, situated within the diploë—a rare form, and differing from others in that it continues to bleed when laid open. (This is explained by the abundant supply of arteries and veins in the reticulated structure of the diploë.)

Subcranial, generally situated between the skull and dura mater, and sometimes in the cavity of the arachnoid. A case of triple cephalhæmatoma is reported by Oui; it appeared after an easy spontaneous accouchement; spontaneous suppuration and opening of the occipital tumor; puncture of the left parietal tumor (the larger one of the two parietal tumors), followed by rapid recovery; non-intervention with the right parietal tumor, which very slowly underwent resolution.

Pathological Anatomy.—The scalp generally retains its natural aspect. Exceptionally its appearance becomes red and livid. Its substance remains uninjured, and the pericranium preserves its transparency. The effused blood is contained in a sac of fine membrane, having all the characteristics of condensed cellular tissue. It rests on the bone, from which it can be easily detached, and underneath the pericranium, to which it adheres more firmly. Points of ossification can be observed on the under surface of this membrane. The earlier writers thought that the outer table of the skull was necrosed, carious, and destroyed, and that the ruptured vessels of the diploë gave rise to the hemorrhage. A bony ring forms in the majority of cases. It begins as soon as the separation of the pericranium is arrested, which is about the second day. This has been said to be only a delusion of the sense of touch, but its presence has been demonstrated by numerous autopsies. It is not, however, always present, being absent in tumors situated near a suture. There are many theories as to its causation. The following, by Virchow, is probably not only the most beautiful, but also the most plausible: The healthy cranium grows by proliferation of the inner layers of the periosteum. If, then, the pericranium, through the blood which is poured out, is held apart from the cranium, the bone-forming layers of the periosteum being still thrown off, they cannot reach that part of the bone for which they are intended, on account of the presence of the blood. Eager, however, to fulfil their office, they join themselves to the bone at the border of the tumor where the bone is still attached. Bland Sutton reports a case which had occurred in a monkey. Autopsy showed the bony ring. Similar formations of bone are observed in rabbits subjected to experimental elevation of the pericranium.

Etiology.—The etiology has occasioned much discussion. The reception of some injury by the child during parturition was long thought to be the cause. A number of observers failed to note that it succeeded difficult labors. The tumor occurred on parts not liable to pressure. Cases are reported after breech presentations, after Cæsarean section, and after painless labor, and it has been observed that a narrow pelvis in the mother is an infrequent accompaniment. It occurs in premature births. These tumors form on children of advanced age and on adults; sixty-six and two-thirds per cent. of the cases are males. While it is very easy to imagine how pressure during parturition might cause the tumors, yet it is very evident that in a large proportion this is not the cause but that it must be some fault of the blood-vessels. Intracranial hemorrhage is in reality a form of apoplexy, and it is quite probable that the tendency is inherited. One case is on record in which the same mother gave birth to three children successively who had cephalhæmatoma. In a case reported by the author, the mother said: "Three of my other children died of convulsions, and I gave this one up as soon as they came on." These other children, too, might have had cephalhæmatomas, and there might have been an inherited tendency; or an unusual friability or thinness of the vessels, or incomplete development of the outer layer of the skull, might have been the cause. If cephalhæmatomas are caused by pressure in breech presentations, this must be due to the action of the cervix on the cord or neck of the child. Pressure during delivery undoubtedly has something to do with the causation of a considerable number of these tumors, yet there are many others which must result from a diseased condition of the blood-vessels, inherited or acquired. Heydecker reports a case which was due, in his opinion, to imperfect ossification of the cranial bones.

Frequency.—The average, so far as it can be learned from the statements of authors, is 1 in every 235 children born.

Location.—It is most frequently situated on the right parietal bone, then on the left, occasionally on the frontal, more rarely on the occipital and in the temporal regions.

Diagnosis.—It is a disease of the newly born. Exceptions: One case has been reported in a child of six months, another in one of twelve months, a third in a man of twenty-six years, a fourth in one of thirty-six, and a fifth in a woman of forty-nine. These, however, are anomalies. One notices a tumefaction, usually one, two, or three days after birth. It develops gradually; it is of fluid character. It pulsates forcibly at the beginning, if connected with an artery; it loses this later, but fluctuation is always present. In size the tumor ranges from that of a hazelnut to that of a mass involving the whole surface of the parietal bone. The tumor is limited by the sutures in the three varieties situated between the pericranium and the dura mater; in the subaponeurotic and arachnoid varieties this is not so. The scalp is natural in appearance in the subaponeurotic variety. The bony ring is almost pathognomonic in the subpericranial variety, but is not so often present in those situated between the cranium and dura mater; in the other varieties it is absent. The diagnosis of internal cephalhæmatoma must be made from the symptoms of brain pressure, twitchings, convulsions, stupor, or paralysis which it may produce. The caput succedaneum occurs in the first twelve to thirty-six hours. Cephalhæmatoma is at birth either absent or scarcely noticeable, grows from day to day until, on the eighth day, it attains its full size, and then, perhaps, the bony ring can be felt. The caput succedaneum pits on pressure, while the cephalhæmatoma does not. From hernia cerebri congenita it may be distinguished by the fact that this pulsates, while cephalhæmatoma simply fluctuates; hernia cerebri, furthermore, is not found on the parietal bones, but on the sutures and fontanels; it protrudes during the acts of coughing and crying, is partly reducible, and then causes slight convulsions. The rim of bone resembles somewhat the elevated ring, but pressure of the finger on the tumor does not find a bony floor as in cephalhæmatoma. The skin over hernia cerebri is thin and hairless, in cephalhæmatoma it is normal. Fungus of the dura mater does not contain fluid, does not fluctuate nor feel doughy, has no bony ring, and the overlying skin is thick and blue. This form of tumor becomes smaller under pressure, and, besides, it seldom occurs in children. Atheroma and fatty tumors occur rarely at such a tender age. They can be differentiated by the trocar, but one must be careful to exclude hernia cerebri before using this instrument. There is no danger of confounding cephalhæmatoma with hydrocephalus externus, and the osseous circle will distinguish the former from aqueous cysts. Telangioma occupies the favorite seat of hæmatoma, but is not covered with hair, pulsates weakly, and is somewhat diminished in size by pressure.

Prognosis.—For the extracranial tumors the prognosis is good, for the intracranial it is bad. Death takes place mostly from exhaustion, brain pressure, and secondary hemorrhage; from rupture of the tumor; from necrosis or caries of the bone leading to perforation; from thrombosis of the cerebral sinus; from extension of the inflammation into the meninges and brain itself; from absorption of ichorous discharge, and from pyæmia. Arthritis, phlebitis umbilicalis, pleuritis, scleroderma, intestinal hemorrhage, caries of the skull, and, in the internal variety, idiocy are among the results which may follow cephalhæmatoma.

Treatment.—Authors are divided; some follow the expectant, others the active plan. Some of those who use the knife wait till the eighth to twelfth day; a few make the incision earlier. The artificial evacuation of the blood is usually unnecessary, and may do harm; as a rule, non-interference is best. If pus forms it should be evacuated. Patton, in the case of his own son, aspirated on the twelfth day, removing twelve fluidrachms of blood. Result was good and Patton recommends it highly. For the external varieties, warm aromatic fomentations, cold spirit lotions, pressure, and setons have all had their day. As treatment in intracranial cephalhæmatoma has not yet been attempted; as the internal is almost always associated with the external variety, the latter being situated directly over the former, in the writer's opinion it would be advisable to trephine the skull to evacuate the tumor.

Edward Sydney McKee.

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CEPHALOCELE. See *Brain.*

CEPHALOMETRY; CRANIOMETRY. See *Skull.*

CEREBELLUM. See *Brain.*

CEREBRO-SPINAL INJURIES. (MEDICO-LEGAL.) See *Traumatic Affections. (Medico Legal.)*

CEREBRO-SPINAL MENINGITIS, EPIDEMIC.—DEFINITION.—Cerebro spinal meningitis (*μῆνιγξ*, a membrane) is an acute infectious disease, with its main local expression, as the name indicates, in the membranes of the brain and spinal cord. Two sets of symptoms distinguish this disease: one common to all the acute infections, and characteristic of general poisoning of the blood; the other peculiar to the local lesion in the coverings of the brain and spinal cord. The combination of these two sets of symptoms and lesions individualizes the disease.

SYNONYMS.—No disease has received so many names, while there is not one against which valid objection may not be raised. Of *cerebro-spinal fever* (Royal College of Physicians) it may be said that while it recognizes the general infection it fails to indicate the part of the brain and cord affected. Cerebro-spinal fever is neither clear nor classic. It is a term "which may be pardoned when used by the laity, but which educated physicians ought not to tolerate" (Stillé). More glaringly faulty, though with abundant recognition of the brain symptoms, are the designations of the older French authors: *Fièvre cérébrale, phrénésie, cephalalgie épidémique, meningite purulente epidémique*, with which may be cited also the German *Hirnseuche*, and the old English terms *malignant meningitis* and *epidemic meningitis*. The early erroneous view of the disease as a variety of typhus fever is perpetuated in the names *cerebro-spinal typhus, typhus cerebralis apoplecticus, typhus syncopalis, phrenitis typhodes, typhoid meningitis.*

The appearance of an hemorrhagic eruption, which characterizes the graver cases of nearly all the acute infections, has been more distinctly associated with this disease in the names *spotted fever* (Gallup), *petechial fever* (Wood), *malignant purpura* (McSwinney), *malignant purpuric fever* (Stokes,) *pestilential purpura* (Banks), *febris nigra* (Lyons), and in its association in this connection again with typhus as a *typhus petechialis* (North), and with a neurosis, as *neuro-purpuric fever* (Mapother). Moreover, cerebro-spinal meningitis, on account of its eruption, has not escaped inclusion under the all-embracing title, *black death* (A. Smith). As was correctly remarked by Minet, nearly a century ago: "It is quite unfortunate that a single symptom—petechiæ—and one that is wanting in a great majority of cases, should have been seized upon to give it the odious and deceptive name of spotted fever, as that name has been applied by European writers to a very different kind of fever."

The opisthotonos, perhaps the most striking single symptom of the disease, which is, however, by no means universally present, has been selected by the Germans to name the disease a *Genickkrampf, Genickstarre, Nackenstarre;* by the Swedes a *Nacksjucka, Dragsjucka;* and by the Italians a *torticollo.* Fancy has exercised its ingenuity in the title *cerebro-spinal arachnitis* (Mayne), a refinement totally unjustified in the morbid anatomy of the disease; and the limits of frenzy have been almost attained by the frantic efforts of Italian writers to cover the entire field of the disease with the names *tifo-apoplettico tetanico* and *febbre-soporoso-convulsivo.* Terms as delusive and diffuse as spotted fever are the popular names *congestive fever, winter epidemic,* and *cold plague.*

From this array of titles, which is by no means exhausted, may be appreciated the difficulty of securing a proper name for a disease from its symptomatology or pathology. The name *cerebro-spinal meningitis* (Hughes, Law, Banks, Moore, and others) is at present the least of all objectionable, and has hence, in the course of time, come into common use, though it gives undue prominence to the local lesion to the exclusion of the infectious character of the disease. As was observed by Valleix, it is "begotten of anatomical bias and an incomplete appreciation of the facts." Gordon attempted to cut the knot of difficulty by calling the disease *cerebro-spinal fever*, with *cerebro-spinal meningitis,* a combination too bulky for practical use.

HISTORY.—Epidemic cerebro-spinal meningitis is a disease of modern origin; perhaps it would be more strictly true to say of modern recognition, for previous to the nineteenth century there was no possible differentiation of this disease and forms of typhus fever, pernicious malarial fever, tetanus, and the various inflammations of the brain and cord, diseases known to be as old as the history of medicine. More recently Davis was justified in the statement that "in regard to the disease promiscuously styled 'spotted fever' and 'cerebro-spinal meningitis,' as reported in our literature, no less than three or four diseases have been confounded together" (Trans. Amer. Med. Assn., xvii., 1866). Hence the possibility is not to be excluded that cases, or even epidemics, of cerebro-spinal meningitis occurred in ancient times. Medical historians (Ozanam, Alpin) have made repeated endeavors to identify this disease with the *phrenitis* of Hippocrates, and with certain epidemics of ancient Egypt, or (Tourdes, Boudin) at least to find its most essential features in the later writings of Forestus, Ignassias, Felix Plater, and Saalman; but the references cited go further to show interest and assiduity in antiquarian research than to confirm their views.

It is, however, not just to claim that there could have been no possible recognition of this disease before the fifteenth century, when the first dissections were made of the spinal cord, for diagnoses in ancient times were wholly based on symptoms; but it is unreasonable to assume the distinct recognition of a disease whose symptoms were not separated from other acute infections or from purely local lesions.

It is generally conceded of cerebro-spinal meningitis that it first attracted notice as a separate disease in Geneva, February, 1805. Perhaps this first notice is due to the fact that the cases occurred in the practice of Vieusseux, an observer as keen as he was frank. He called the malady a *fièvre cérébrale ataxique,* and admitted that neither he nor his colleagues had ever seen a similar disease. These first victims were a woman and three children, two of whom died within twenty-four hours. The disease extended gradually to neighboring houses, in one of which four out of five children were attacked, and died within fifteen hours. It was characterized by suddenness of attack, vomiting, excruciating headache, stiffness in the back of the neck, dysphagia, and convulsions (Laveran, "Dict. encyclop. des sc. med.," 2d ser., 5 to 6, p. 648). A young man in an adjoining house died on the same night of the attack, showing a violent discoloration of the whole body. Thirty-three persons fell victims to this first outbreak of the disease, which lasted until May. The post-mortem examinations made by Mathey upon some of these cases revealed gelatinous exudation covering the convex surface of the brain, yellow pus posteriorly and about the optic commissure, cerebellum, and medulla oblongata. It is remarked of this first attack that it remained quite strictly localized.

The next outbreak of the disease, with unmistakable signs, occurred in our own country, with the first cases at Medfield, Mass., March 1806. These cases formed the preface to a long chapter in the history of the disease, known then as "sinking typhus," ten years in duration, during which time it extended over, but remained confined to, the New England States. Meanwhile the disease made its first appearance in France, at Grenoble, where it prevailed during the months of the spring of 1814, remaining confined to the soldiers lately arrived from the army of Mont Blanc. Comte describes it as a malady characterized by stiffness of the neck, with headache and delirium among its prominent symptoms, with traces of inflammation in the brain and cord observed on autopsy among its lesions. During the next year, Rampont described four cases at Metz, distinguished by the same array of symptoms and lesions. With the exception of an extensive endemic in Vesoul, in 1822, which differed from previous attacks in its preference for the civil population, the disease did not show itself again in France until January, 1837, when it broke out with great virulence in the garrison at Bayonne, and rapidly extended to invade the neighboring barracks at Dax, Meignon, and Tartos, and to assume, later in the course of the year, epidemic proportions, reaching Bordeaux by December of the same year; Rochefort, January, 1838; and Nîmes and Avignon, in the interior, by the end of the year. It is remarked of this outbreak, at a place appropriately named Aigues-Mortes, where it first appeared in November, 1841, remaining confined to the civil population, and continuing until March, 1842, that it attacked 160 persons of whom 120 died.

The same regiment of light infantry which transported the disease from Bayonne to Rochefort conveyed it also to Versailles, where it appeared in February, 1839, six men inhabiting the same room being attacked within a period of a few days. Paris made its first acquaintance with the disease, after the lapse of several years, in December, 1847. It continued to prevail in Paris up to May, 1849, confined exclusively to the inmates of the garrison and the prisoners at La Force, in which latter place ten of the twelve persons attacked fell victims to the disease.

After France, Italy was invaded, the disease first appearing in the kingdom of Naples, in the winter of 1839–40, and spreading thence, in the following winter, to the lands of the church. In the same year (1839), the most eventful in the history of the disease, as that from which dates any exact knowledge concerning its nature and individuality, cerebro-spinal meningitis first showed itself in Algiers, where it continued to number victims with annual recurrence in various parts of the land up to 1847.

After the first recognized appearance of the disease, from 1805 to 1816, accounts of it cease for six years, when, in 1822, it reappeared at Vesoul, in France, and at Middletown, Conn., to which remotely separated places it remained quite strictly confined. Then, after an additional five years, it again showed itself, in 1828, in Trumbull County, Ohio; in 1830 in Sunderland, England, and in 1833 at Naples. In 1842, when the disease again visited the United States, it appeared almost at the same time in Louisville, Ky.; Rutherford County, Tenn.; and Montgomery County, Ala.

Sweden was not reached by the disease until 1854, when it suddenly appeared in Gothenburg, extending thence in the course of the following year as far north as the city of Kalmar. Then, after a complete cessation of six months, it showed itself in a series of small epidemics extending a degree and a half farther north, and with this fitful, almost freakish appearance and disappearance, it hovered about that country for seven years, striking lightly in one place and like lightning in another, until it had killed in all 4,138 of its inhabitants. It was only during the last two years of this visitation of Sweden that the disease first showed itself in Norway (March, 1859), in very limited extent, but in such severe degree as to have carried off in the county of Opdal 14 of the 29 persons attacked.

Strange to relate, the first invasion of Germany did not occur until very late in the history of the disease. Disregarding as unauthentic the earlier communications of Würtemberg physicians, Hirsch feels compelled to accept the statements of Rinecker, who reports with due detail cases occurring in Würzburg, June, 1851, both in hospital and in private practice. But the first attack of any severity or extent was reserved for a later date and place, namely, for Silesia, Posen, and Pomerania, in 1864. Excepting Bamberg, anything like alarming proportions were not reached anywhere in Germany, though the disease prevailed with some severity at Erlangen, in July, 1864.

The comparative exemption of certain countries is another, and as yet inexplicable, feature of the disease, more especially of countries contiguous to and under the same general conditions as those severely visited. Thus while Ireland has suffered repeated attacks—a severe epidemic having occurred in Dublin, in 1866, wherein "the British forces suffered much in proportion to their average strength"—England has never had anything more than isolated cases, and Scotland, where the elements of crowd-poisoning are greatest, has never experienced an epidemic of the disease. And while epidemic proportions have been reached in Germany on the north, and in Italy on the south, Austria has remained almost entirely free from attack.

Our own country seems to have offered from the start a fertile soil for the development and spread of cerebro-spinal meningitis, and since the year 1842, when the disease began to make excursions over the various lands of Europe, it has become almost indigenous with us. Mention has been made already of the simultaneous occurrence of the disease in Alabama and Pennsylvania, in 1848. In the following year it made its first appearance in New Orleans, and during the following decade sporadic cases occurred over various parts of the country, as in North Carolina, in 1856, and Massachusetts, in 1857. Four years later (1861), more and more frequent cases are reported, from Connecticut, Indiana, Kentucky, and Missouri. Three years later still (1864), the disease again appeared in Pennsylvania, carrying off 400 children of the 6,000 inhabitants of Carbondale. It was during the winter of these early sixties that the disease began to prevail in both armies of the rebellion, assuming a very malignant type in North Carolina, where it affected citizens and soldiers equally in the Union and Confederate armies alike (Stillé).

Epidemic recrudescences were observed in New York, 1872; Boston, 1874, and again in 1896–97; Cologne, 1885; Vienna, 1886 and 1897, and in Berlin, 1896.

The view that cerebro-spinal meningitis did not extend to or prevail in other continents than "North America and Europe, and the vicinity of the latter," has been quite abandoned, as epidemics have been authentically reported by Kotsonopulos, at Nauplia, in Greece, in 1868; by Höschelman, in the Crimea, in 1868; by Diamantopulos, in Magnesia and Smyrna, in 1869–70; and by Sandreczky, in Jerusalem, in 1872.

Without attempting even to mention all the epidemics that have prevailed in various parts of the world, it may be stated that, though doubtful cases prevailed before this time, cerebro-spinal meningitis belongs to the nineteenth century, and that its history naturally falls into three periods, quite distinct: the first embracing the first cases of "ataxic cerebral fever," observed at Geneva, in 1805, and of "spotted fever," in Massachusetts, in 1806; the second commencing with the outbreak at Bayonne, in 1837, and extending over various parts of Europe and America up to the year 1866, gradually merging into the third or present period, when the disease has become more or less universal. Thus it may be said of this disease that it began in sporadic form, to become endemic in the course of the first observations; that on its second appearance it assumed the proportions of an epidemic in various lands, to finally overleap all barriers as a true pandemic disease.

General Remarks.—Cerebro-spinal meningitis belongs among the rarest of epidemic diseases. Since the establishment of the disease as a pandemic affection, sporadic cases are of continual recurrence, but these cases remain isolated as a rule. The practitioner is often surprised at being confronted with a pronounced case of this disease in a crowded tenement house, in a palatial suburban residence, in a barrack or jail, in the ward of a hospital, in a distant farmhouse, when no similar case may have been reported, and probably no other case may show itself for years. So that individual cases, not distinctly marked, are apt to be overlooked for a time, or erroneously diagnosticated, and numerous instances are recorded in which the diagnosis has been fully established only upon autopsy.

Now that the disease has made itself more familiar by frequent or constant appearance, much of the obscurity surrounding it is being dissipated, and cerebro-spinal meningitis is seen to take its orderly place among the acute infections, with its own specific cause, characteristic signs, and peculiar lesions. It has been stated already that two sets of symptoms distinguish this affection: one common to all the acute infections, and the other peculiar to the anatomical lesions of this particular disease. But, as in all the acute infections, either set of symptoms may assume prominence in an individual case. Niemeyer's statement, "I must again repeat that the symptoms and course of epidemic cerebro-spinal meningitis may be fully explained by the changes in the meninges of the brain and spine," covers only the cases of normal or protracted course, and will not apply to the foudroyant forms of "a disease in which," as Stillé remarks, "the septic element sometimes so far overrides the inflammatory as to destroy life before the latter has developed characteristic change." If this explanation is borne in mind it is seen that cerebro-spinal meningitis does not differ more widely from other acute infections than they do from each other.

The view that cerebro-spinal meningitis is a cerebral variety or form of typhus fever had advocacy enough in the earlier history of the disease to have fixed the name of typhus in connection with it. This view, which was ably supported by Boudin, Murchison, Upham, Baltzell, and others, was based upon a seeming analogy of symptoms—suddenness of attack, petechial eruption, brain symptoms—in the two diseases, and an occasional coincident prevalence. But more extensive observation has proven beyond doubt that there is nothing more in common between these diseases, to use the language of Burdon Sanderson, "except so far as each was due to a specific poison." Holmes writes graphically upon this question: "That a disease which is sometimes almost as sudden in its invasion as a stroke of lightning; which is rarely suspected of being contagious; which gives us a solitary case in a ship of war, a single case in a boarding-school, two cases only in an almshouse; which in civil practice affects the villages and isolated farmhouses of the interior (where typhus running the ordinary course is unknown) as much at least as the larger cities; which in a great majority of cases is fatal in a few days, or even hours; the mortality of which is very variable—such a disease presents so many points of difference, when compared with British typhus, that we should hesitate before pronouncing the two identical." Clymer quotes Tourdes, Levy, Lebert, Niemeyer, Stokes, Gordon, and Hirsch, in protest against this view, citing from Hirsch the statement: "Apart from its very obscure pathological essence there is hardly anything in its symptoms or lesions which brings epidemic meningitis within that comprehensive and elastic term—typhus." Differing as they do in all essential particulars, Radcliffe says, "doubt can only arise when the two diseases prevail together."

Any connection of this disease with malaria has been disproved in the same way. Such fluctuations occur in the course of certain cases of cerebro-spinal meningitis as to simulate to some extent the periodicities of malaria, and the "intermittent" is recognized as one of the forms of the disease. But the geographical study of the two affections reveals the fact that cerebro-spinal meningitis does not visit malarious countries with special frequency or virulence; that it attacks regions entirely exempt from malaria—the high, dry, and sandy plateaus of Central Franconia, for instance; that it shows preference for the winter rather than for the autumnal season; that the two diseases have, in short, different spatial and temporal relations, or, if they should coincide, the symptoms of meningitis do not show increased virulence. Ziemssen quotes in this connection from Bonsaing, who noticed that the epidemic of meningitis at Pola "did not seek out the notoriously malarious parts of the city"; and that "during the epidemic, and after its disappearance, malarial fevers were almost entirely absent." If further proof were wanting to establish the non-identity of these affections it could be found in the absence in meningitis of enlargement of the spleen and liver, and of the melanæmia, so characteristic of malarial affections, in the age of the victims of the two diseases, in the total inefficacy of quinine in controlling the disease, and above all in the examination of the blood for the plasmodium malariæ, the specific cause of malaria, which is never found in pure cases of cerebro-spinal meningitis. These observations, which establish the independence of cerebro-spinal meningitis, meet with striking confirmation at the hands of Diamantopulos, in his account of the epidemic in Asia Minor in September, 1870. Any connection with typhus or malaria is, this author states, "positively to be denied, as during the entire prevalence of meningitis in Magnesia, no case of either of these diseases occurred" (*Schmidt's Jahrbücher*, 196, p. 239, 1882). However, typhus fever or malaria may coexist with cerebro-spinal meningitis.

Lastly, it is claimed that cerebro-spinal meningitis is not confined to man, but that characterstic symptoms and lesions have been observed in some of the lower animals. Gallup observed of the epidemic in Vermont in 1811 that "even the foxes seemed to be affected, so that they were killed in numbers near the dwellings of the inhabitants"; and Smith remarks of the outbreak in New York, in 1871, that "it was common and fatal in the large stables of the city car and stage lines, while among the people the epidemic did not properly commence until January, 1872" (Stillé). Clymer quotes from Law, of Dublin, who writes, in reporting several sporadic cases of the disease in 1865: "It is a fact worthy of recording that at the time we were attending this lady, nine rabbits out of eleven, which her son had, died all in the same way; their limbs seemed to fail them, they fell on their sides, and then worked in convulsions, and died. Two hens fell lifeless from their roost." Statements of this kind must, however, be taken with much allowance, as the symptoms cited by no means identify the disease, and the lesions found upon the bodies of three of the rabbits examined—"congestion of the vessels at the base of the brain" in two, and in the other "vascularity of the membranes of the spinal marrow"—are too vague and indefinite for a diagnosis. The same reservations must also be made in the case of the so-called epizoötic of meningitis among the domestic fowl in Algeria in 1846, among the dogs and hogs preceding the epidemic in Ireland in 1868 (Collins and Ferguson), and more markedly still of the disease among the artillery horses in Grenoble, 1814, and the livery-stable horses in Paris, 1844 (Villatte), where post-mortem examinations were not made at all.

ETIOLOGY.—Every attempt to connect cerebro-spinal meningitis with any special climate has turned out a signal failure. The disease has ranged, almost at will, from Gibraltar in the south of Spain, and from Algiers in Africa, to the most northerly towns and villages in Norway and Sweden. And in our own country cases have been reported from Maine to Mexico. The intertropical regions proper have as yet remained exempt from the disease, but the prevalence of it elsewhere, in seasons of extreme heat and humidity, would indicate this exemption to be an accident of time rather than of space.

Equally futile has been the endeavor to fix the disease in connection with any special soil. The coast of France, the valley of the Rhine, the hills and mountains of Calabria and Algiers, up to an elevation of a thousand feet and more, the marshy banks of the Garonne at Bordeaux, the recently inundated fields at Avignon and Aigues-Mortes, the wet camping-grounds at Newbern, N. C., the rocky sides of Gibraltar, and the dry, sandy plateaus of Franconia, have all offered equally fertile soil for the development and dissemination of the disease. Subsequent writers subscribe with unanimity to the statement of Hirsch that "conditions of the soil seem to be in every respect irrelevant to the occurrence of the disease."

But the *season of the year* has more to do with the dissemination of this disease. Perhaps the most striking fact apparent in the study of the etiology of this affection is the frequency of its occurrence during the colder months of the year. Thus, of 52 epidemics in France and Switzerland, 23 occurred in winter, 13 in winter and spring, and but 2 in the midst of summer; while of 16 epidemics in our own country, 6 occurred in winter and 5 in winter and spring. The epidemics of Sweden and Norway, Denmark, Spain, and the Netherlands all occurred in winter. Various explanations have been offered to account for this preference of the colder season. That cold alone, or mere reduction of temperature, will not account for the genesis of the disease is proven by the fact that epidemics have occurred in the midst of summer, even in hot countries, as in Italy, the South of France, and the Southern States of our own country. Moreover, many cold countries—North Russia, Siberia—have never known the disease at all. Obernier attributes the preference for the colder months of the year to the fact that people are more confined to houses at this season, are subjected longer to the evils pertaining to the "house climate."

Leaving for the present extrinsic considerations, some attention must now be paid to those that are intrinsic; and first, concerning *age*.

While it is acknowledged of cerebro-spinal meningitis that an almost freakish variation has occurred in its attack of individuals, it is generally conceded that it shows predilection for the period of youth. Thus, it is stated by Hirsch that of 1,267 fatal cases in Sweden in the years 1855–60, where the age was stated, 889 were under fifteen years, 328 from sixteen to forty years, and 50 over forty years of age. But some qualification must be made of these statistics, from the fact that cerebro-spinal meningitis is notoriously much more fatal in the early years of life. Stillé quotes from Schweitzer to the effect that in 1866, in the Kronach district (Germany), of 115 cases, 75 occurred under the seventh year, 22 between the seventh and twelfth years, and 10 between the thirteenth and twentieth years; and from J. L. Smith, from the "Reports of the Board of Health of the City of New York," who found that of 975 cases, 771 occurred in persons under fifteen years of age, and 336 in children under five years of age. In some epidemics children have been the only victims of the disease. This was the case at Conshohocken, 1863 (Reid); Neustettin, 1865 (Litten); Westchester, N. Y., 1872 (Rodenstein); and at the Petitburg Colony, 1848 (Ferrus). In other cases the disease attacked children first and adults later, as at Polzin, 1864 (Lehmann); Forchheim, 1864–65 (Seggel); Hanover, 1865 (Neynaber), and Jerusalem, 1872 (Sandrecky). Emminghaus, who reports these data in his article on this disease ("Handbuch der Kinderkrankheiten," 2, 483) makes the collective statement, from over fifty extensive observers, that of 1,435 cases, 1,133 were under fifteen years of age. All authors agree concerning this, as of all the acute affections, that the period of earliest childhood (suckling) is not affected in like degree. Smith found the proportion of liability to attack at the ages of under five years as 461; five to ten, 204; ten to fifteen, 106. Niemeyer's figures for the first two quinquennial periods are as 54 and 40, and Mende's as 47 and 29. On the other hand, in Berlin, the disease was wholly confined to adults.

It is definitely ascertained, regarding the period of childhood, that sex makes no difference whatever, and though different results have been reported in different epidemics affecting adults, it is probable that the average number of each sex attacked remains about the same.

It is commonly stated that individuals of robust, vigorous constitution furnish the greatest contingent of cases. Hirsch remarks that statements to this effect were made to him by relatives and medical men, and Pfeiffer and Heiberg corroborate these statements from their own observations. Yet all such statements of individual observations must be taken with some allowance. We may recall how universally prevalent was this same idea regarding pneumonia but a few years ago, whereas it is now conceded that the very reverse is true. At any rate it has been remarked by Leyden, of cerebro-spinal meningitis, how often weakly children are attacked, and by Ziemssen how frequently the victims of this disease were subjects of chronic brain affections.

Individual epidemics have been frequently noticed to have been distinctly connected with different social states. The selection of *soldiers* as exclusive victims has made this disease a familiar guest in army life. The recent conscripts and new recruits have been often the sole victims of the disease. Pfeiffer says the disease "prefers winter, soldiers, and children." At times the disease has remained strictly confined to certain corps or companies. On the other hand, other epidemics have spared the garrisons and camps to attack, as at Leipsic, the civil population. During the War of the Rebellion citizens and soldiers suffered alike, and the colored race was not spared, whereas during the outbreak in Texas there was not an instance of the disease occurring among negroes.

The same caprice has been exhibited in different epidemics with regard to the inhabitants of cities and towns. As a rule the rural population has suffered most. In this connection Stillé says of the disease: "It has passed by large cities reeking with all the corruptions of a soil saturated with ordure and populations begrimed with filth, as Vienna, Berlin, Paris, London, and New York, to devastate clean and salubrious villages and the families of substantial farmers inhabiting isolated spots." Roth remarks of the 42 deaf-mutes attacked at Bamberg that 38 were from rural districts, while only 4 were from the city itself. What made this circumstance the more remarkable was the fact that the disease prevailed in Bamberg in unusual severity.

A strict localization of the disease to certain houses, flats, or stories has often been observed. Prisons, workhouses, orphan asylums, constitute at times breeding-places of cerebro-spinal meningitis. The epidemic in Ireland, 1846, was strictly confined to the prisons, and the disease broke out with the same seclusion in the orphan asylums in Philadelphia and Vienna in 1863, Washington in 1869, and Jerusalem in 1872. Keene reports a similar outbreak in the Naval School at Newport in 1863.

Fatigue of the body (Bollet), exposure to cold and rain (Mannkopf), traumata (Leyden), sunstroke (Schweitzer), the pre-existence of other acute infectious disease (Immerman and Heller) have all been cited as accidental predisposing causes in individual cases, but no one now would claim that any of these factors stands in any direct relation to the disease. The same remarks apply to the alleged psychical causes of the disease, as fright from a peal of thunder (Ziemssen), mental strain, etc. The frequency with which the disease has broken out in school has the same significance as attacks at night in bed.

The preference for the colder season and the predilection for the age of childhood are factors which are universally acknowledged, but so many exceptions have been noticed to these rules as to deprive them of the force of laws governing the disease.

The mode of onset of the disease, the symptoms presented during its course, and the characteristic lesions encountered in the internal organs, assign the disease unmistakably, in its nosological relations, with the acute infections. Examples of infection by contagion have been reported by Ziemssen, Prew, Neynaber, and others, and instances have been reported by Niemeyer and Fraentzel of transportation of the disease by detached troops. Hence search was made for something characteristic in the way of micro-organisms. Schweninger (*Schmidt's Jahrbücher*, cxcvi., p. 130, 1882) speaks of having found enormous accumulations of germs (*massenhafte Pilze*) in the brain in cerebro-spinal meningitis. Leyden (1883) found in the exudation and in the tissue of the pia mater of a sporadic case the diplococci, formerly described by Eberth and Klebs, of oval form, united in short chains of two or three members, and assuming color with fuchsin and methylene blue. Marchiafava and Celli (*Gaz. degli Ospitali*, 8, 1884) made the same examination in two cases of epidemic meningitis, discovering constantly in preparations colored with a weak alcoholic solution of methylene blue, oval micrococci isolated or united as in diplococci. The micrococci were partly free and partly embedded in the protoplasm of the white blood corpuscles, rarely in the endothelial cells. Anything approaching chain-like formations were not observed. The tissue of the pia mater contained the same structures as the exudation, but blood from the right heart and splenic pulp proved entirely free. Ughetti (*Deutsche med. Wochenschrift*, June 19th, 1884) reports, also, of examinations made in one of twenty-one cases of the disease, at Ulsterbianco (Italy), the presence of numerous spherical micrococci, partly isolated and partly grouped in pairs, in the sero-purulent fluid from the ventricles of the brain. The author injected a syringeful of this fluid under the skin of the back or abdomen in four rabbits, with entirely negative results. In another case the blood drawn by cups along the spinal column contained "innumerable micrococci" of exactly the same appearance as those from the ventricular fluid. This blood injected into three rabbits by the hypodermatic method produced likewise no symptoms worthy of note. Aufrecht (*Deutsche med. Wochenschrift*, vi., 4, January 24th, 1885) found micrococci floating free in the serum, and embedded in the pus corpuscles; further, in miliary deposits in the liver, lung, and kidney, as well as in the splenic pulp and blood from the heart. They could be colored with fuchsin, and were endowed with active motion. Many other observers, among them Leichtenstern (1885) and Rovsing (1886) reported finding bacteria in meningitis.

Netter, Fränkel, and Foà and Uffreduzzi (1886), studying independently cases of cerebro-spinal meningitis, reported finding an encapsulated coccus resembling the Micrococcus pneumoniæ crouposæ of Sternberg (pneumococcus). The micro-organism was found in the cerebro-spinal fluid in cases of meningitis independent of pneumonia. The same micro-organism was found during the following year, by Weichselbaum and a number of other observers, in cases of meningitis secondary to pneumonia. Both Netter and Weichselbaum observed that the injection of the pneumococcus into the cranial cavity would produce meningitis.

Weichselbaum (1887) isolated from six cases of cerebro-spinal meningitis a micro-organism which he called the Diplococcus intracellularis meningitidis. The presence of this diplococcus, which is also known as the meningococcus, in cerebro-spinal meningitis has been confirmed by many investigators. Netter believes that the meningococcus may be a degenerated form of the pneumococcus, but this opinion is not generally accepted. Osler would give to the cases caused by the pneumococcus the dignity of a special place in nosology as a pneumococcic meningitis, and would ascribe cerebro-spinal meningitis, both sporadic and epidemic, to infection by the Diplococcus intracellularis meningitidis.

Bonome (1889), in six cases of cerebro-spinal meningitis, found a micro-organism which he named the Streptococcus capsulatus meningitidis. Netter regards this organism as a variety of the pneumococcus, a view which is shared by Foà and Uffreduzzi but opposed by Bonome.

To account for the ingress of micro-organisms into the recesses of the brain and spinal cord Eichhorst invokes the action of the lymph vessels in conveying the excitants of inflammation from neighboring structures, and Weigert calls attention to the destructive suppurative changes which he has encountered in the upper cavities of the nose. In this connection Strümpell calls attention to the remarkable loss of the sense of smell, and to the prefatory coryza or nasal catarrh which he has repeatedly seen in this disease. Sears (Boston *Medical and Surgical Journal*, August 9th, 1888) noted the frequency of pharyngitis during epidemics of cerebro-spinal meningitis.

A case of intra-uterine meningitis has been reported by Gradwohl (Phil. *Med. Jour.*, vol. iv., p. 445). The mother died at the seventh month of pregnancy, without aborting. Cultures of the diplococcus intracellularis meningitidis were obtained from the meninges of both mother and fœtus, and both showed the meningeal lesions of meningitis.

One attack of cerebro-spinal meningitis confers the immunity common to most of the acute infections. Second attacks are rare. One such case is reported to have occurred in an individual named Lacon, who left the hospital cured, February, 1841, to return February 4th, 1842, affected with the same disease, which proved fatal on the following day (Companyo: "Essai sur la mén. cérébro-spinale," p. 76, Paris, 1847).

PATHOLOGY.—The disease begins with the aspect of an acute infectious malady, and maintains it throughout its course. As a rule the onset is sudden, with the impress of profound toxæmia. A chill comes on in the midst of apparent health, with vomiting, excruciating headache, and rapid prostration. Tenderness and stiffness in the back of the neck supervene in the course of a few hours. The face is pale, the expression anxious and strange, the extremities are stiff and tremulous. The slightest motion intensifies the pain in the whole body, the act of vomiting makes it atrocious. A sense of formication with hyperæsthesia is felt first, as a rule, in the lower extremities, to which it may remain confined, or it may extend over the whole body. The special senses of sight and hearing become likewise supersensitive. A flare of light, the slam of a door, the rumble of wheels in the street, a touch of the bed, produce a condition of agony. Even the approach of an attendant with the gentlest ministrations is watched with apprehension. Temporary relief of this distress is secured during a state of sopor or stupor which may occur, from which the patient awakens or is aroused—children often with a *cri hydrocephalique*,—with a renewal of the same symptoms in greater or less degree.

In the course of a few days, often during the same day of attack, the stiffness of the neck increases to rigidity, or extends to constitute the characteristic opisthotonos. Convulsive twitchings of the face, or clonic spasms in the muscles of the extremities, may now occur, with delirium or outbursts of maniacal excitement under the slightest provocation.

Soon various eruptions, especially herpes and petechiæ, more rarely erythema nodosum, ecthyma, and pemphigus, begin to make their appearance, at first, as a rule, on the face, to extend later over large tracts of the body, or over the whole body (spotted fever).

The temperature curve of the disease distinguishes itself by its irregularity. As a rule, it rises quickly at first to 102° F., or even 104° F., to fall in the course of a few days, or to undergo fluctuations in extreme degree, sinking at times below the normal (Laveran). An extreme hyperpyrexia not infrequently precedes a fatal termination, which is usually attended, however, with a reduction to correspond with the marble coldness of the skin.

The pulse increases out of all proportion to the temperature, to experience, later on in the attack, greater fluctuation in frequency, volume, and tone than in almost any other disease. The same variations are noticed also in the acts of respiration, which are often quick and slow in the course of the same hour of the day.

The tongue is usually dry and red, in bad cases fissured and fuliginous, and sordes in these cases cover the teeth and gums.

The abdomen is sunken and retracted, often to such a degree as to show the outlines of the bodies of the vertebræ, or make distinctly apparent the crests and prominences of the iliac bones. Constipation is present, as a rule. The urine flows scantily and slowly from a paretic bladder, or in the worst cases is voided unconsciously in bed. Trismus, singultus, delirium, and coma, with ecchymoses and meteorism of the abdomen, mark the speedy advent of the close of the disease; or relaxation of the opisthotonos, relief of the pain in the head, with critical sweats or enuresis, indicate a favorable resolution.

Although different epidemics exhibit great variations in the degree and number of the symptoms cited, cerebro-spinal meningitis usually shows itself besides, in the typical cases mentioned, in one of three distinct forms or types, namely: the abortive, the intermittent, and the siderant or foudroyant.

The abortive form exhibits all its symptoms in the lightest grade. The headache is slight, the stiffness of the neck trivial or temporary, and vomiting may not occur, or may not recur after the first attack. Such cases often entirely escape recognition, or are diagnosticated only because of the prevalence of an epidemic of the disease.

The intermittent form is noticed more especially in certain epidemics, though such cases are wont to occur in any extensive outbreak of the disease. Not infrequently isolated sporadic cases assume this form, to the great embarrassment of the practitioner. Quotidian and tertian intermissions or remissions occur in all the symptoms of the disease, leading often for a time to erroneous prognostications. The intermissions are by no means as distinct, as a rule, as the periodicities of malarial disease, yet they prove exceedingly deceptive to superficial observation. The exacerbations correspond undoubtedly to the irregular invasions or advances of the disease.

The foudroyant is the fulminant form, in which the patient is often killed by the force of the poison before permanent local lesions have time to develop. These are the cases which destroy life in the course of from six to thirty-six hours. The patients in these cases are often suddenly stricken with unconsciousness and convulsions, sometimes preceded for an hour or two with vomiting and pain in the head, in which condition they are carried home, pallid, cold, or lightly cyanotic, showing no reaction to the most powerful stimulants, to sink into coma and speedily succumb.

Cerebro-spinal meningitis is particularly prone to a number of grave complications and sequelæ, prominent among which may be mentioned paralyses and paresis of various organs and members, and profound, often permanent, lesions of the eye and ear.

Morbid Anatomy.—The external appearance of the body in cerebro-spinal meningitis varies with the duration of the disease. Rapid or foudroyant cases exhibit no change, but cases of longer duration show an emaciation which in protracted illness simulates that of cancer and tuberculosis. No trace of eruption is discoverable, as a rule, though occasionally the surface remains covered with petechiæ. Suggillations form quickly and in quantity over the body, and post-mortem rigidity sets in soon. Moreover, decomposition begins unusually early in rapid cases, as in other acute infections. In the most chronic forms, with extreme emaciation, bed-sores are common and extensive.

The muscular tissue is, in the foudroyant cases, brown and fragile, in cases of average duration more pale from loss of blood. The molecular change of fatty degeneration invades its structure, and gives it the appearance, which is especially remarked of the heart, of being strewn with sand.

The condition of the spleen varies greatly. It is usually found swollen, in fulminant forms, with deeply darkened pulp, but not infrequently it is shrunk to such degree as to show a wrinkled capsule. In average cases it is rather the rule to find this organ of diminished size. As might have been expected, the intermittent forms show no enlargement of the spleen. The cloudy swelling, fatty and granular degeneration of the kidney and liver, ecchymotic state of the mucosæ, œdema of the lungs, effusions in the serous sacs, post-mortem softening of the stomach, swollen condition of the mesenteric glands, dark color and altered consistence of the blood, are changes which belong to all the acute infections, and are especially marked in this disease.

The characteristic lesions are encountered at the anatomical seat of the disease, in the membranes of the brain and cord. But, as already stated, in the fulminant forms these changes may be absent altogether, and Woodward claims that cases of even more protracted course may be marked in this way. There were two classes of cases observed, he says, in the War of the Rebellion. "In the first the autopsy disclosed grave anatomical lesions of the cerebro-spinal axis, accumulations of serum, sero-pus, pus, or tough yellow lymph, especially in the ventricles about the base of the brain and in the upper part of the spinal canal. In the second class of cases no perceptible anatomical lesion in the cerebro-spinal axis was observable." The author further observes: "These two classes of cases rest upon equally reliable evidence, and are not to be disposed of on the supposition that the latter represent merely an early stage of the former, since it is to be remarked that *both* anatomical conditions appear to have been found indifferently in protracted cases as well as in those which proved suddenly fatal" (Clymer, Aitkens: "Sc. and Pract.," 1872). Considering the difficulty of making sections of the vertebral column and of establishing an accurate diagnosis between this disease and pernicious malaria without it, we may still look with some degree of scepticism upon the protracted cases without lesions. Most of us who form our own observations in civil practice with the greater leisure for investigation, will still agree with Valleix, who remarked, long ago, "that when there is more or less absence of the meningeal changes, it is among those who have been struck down by the disease as by a thunderbolt." Light lesions are easily overlooked. Thus in the two rapid cases reported by Levick, with unappreciable change, Parkes calls attention to the omission of stating whether or not there was opalescence or unnatural dryness of the membranes. We are not to forget, also, how quickly even intense hyperæmias fade away entirely in the short interval between death and the autopsy. Leyden reports a case of this kind in which Recklinghausen made the examination.

On opening the skull the membranes of the brain are revealed in a state of intense hyperæmia. The sinus longitudinalis is distended to tension of its walls, and all visible vessels are filled to their utmost capacity. In fulminant cases there may be no trace of exudation, but the pia mater is already opaque and lustreless, sometimes ecchymotic, from infiltration into its texture. The substance of the brain and cord is œdematous and softened in the most superficial layers.

In cases of longer duration the dura mater is stretched tense by the effusion beneath it, punctate hemorrhages are diffused over its surface, and the hyperæmia involves the porous substance of the bones of the spinal column, whose spongy structure appears saturated with blood. The pia mater is reddened with distended vessels, is opaque in some places, ecchymotic in others, and is softened in spots or more extensive surfaces. The first exudation is a light, clear or amber-colored serum, which soon becomes an opaque milky fluid of semi-gelatinous or mucilaginous consistence, sticky, "drawing to a thread," which later becomes greenish, "leek-green," or yellowish with pus. The viscosity of the exudate is due to the presence of mucin (Klebs). The effusion occurs first in the subarachnoid spaces and along the course of the vessels of the pia mater at the base and sides of the cerebrum, in the fissure of Sylvius and between the cerebrum and cerebellum, or extends over the whole surface of the brain to form a veritable cap. Or the exudation, more limited to the base, surrounds the emerging nerves, dissecting up their investing sheaths and following them out in their course. Both Tourdes and Netter have observed purulent flocculi in the fluid that is usually found in small quantities in the cavity of the arachnoid. In the spinal column the exudation is deposited first along the posterior aspect of the cord, as determined by gravity, but soon extends to its lateral surface and to affect or follow out the spinal nerves in the same manner as in the brain. However, Tourdes and Netter have each reported a case in which the false membrane was confined to the anterior surface of the cord. The thickest masses of exudation are found in the cervical and lumbar regions of the cord, though effusion in spots, bands, or islands occurs irregularly throughout its course. In its advance the suppurative process invades the sheath of the optic nerve to travel along its course, infiltrate the orbital fat, to account in life for an iritis, choroiditis, or an all-destructive panophthalmitis. So, also, implication of and transit along the facial and auditory nerves lead to destructive changes in the ear.

As a rule there is no change in the arachnoid. Even the visceral layer of the arachnoid is not adherent to the false membrane beneath it but may be readily separated from the underlying purulent effusion by simple inflation. Sometimes parts of the arachnoid appear whitish or opaque, especially in old cases.

But the ravages of cerebro-spinal meningitis do not remain confined to the membranes of the brain. Mention has been made already of œdema of the substance of the brain and cord in rapid cases, and more profound lesions are to be observed in cases of longer duration. Strümpell (*Deutsch. Arch. für klin. Med.*, xxx., 5 and 6, p. 505, 1882) described in detail these conditions. His autopsies revealed in nearly all the cases such participation of the brain and cord as to justify him in naming the disease a meningo-encephalitis and meningo-myelitis rather than meningitis alone. Beneath the inflamed membranes lies a border zone of hyperæmia and infiltration, composed of distended vessels, perivascular accumulations of round cells which dip deep into the substance of the brain, or more especially the spinal cord, with occasional punctate hemorrhages up to the size of a millet seed. Disseminated depots of pus of various size, with even larger abscesses, more especially in the substance of the brain (four cases), were noticed as a rule. But, aside from the effects of direct mechanical disturbance, there were few visible histological changes in the ganglion cells and fibres of issuing nerves.

Although these exudative changes belong more especially to the average or more protracted cases, they have been noticed also in the cases of short duration. Thus Fronmüller reports the case of a girl, aged fourteen, who died in four days, when the central canal of the cord was found dilated and "filled with pure pus"; and Gordon speaks of a case in which "purulent effusion was found, although the whole duration of the attack was under *five* hours" (Hartshorne's "Reynolds," p. 306.) More credible is the report by Ziemssen, of an "exquisite case," in which the cord was wholly embedded in pus at the end of eleven days.

The changes in the ear have been studied especially by Heller, who found the tympanum, vestibule, and the semicircular canals of both sides containing pus, which bathed the facial and optic nerves. The purulent fluid may be confined to either the middle or the internal ear, but usually is present in both. Acute otitis has been frequently observed preceding an attack of cerebro-spinal meningitis. In such cases the affection of the ear would seem to be primary and the meningitis due to an extension of the inflammation. Heller, on the other hand, would attribute the affection of the ear to the propagation of the inflammation from the meninges along the nerves to the ear; and Moos believes that the inflammation of the ear and meninges occurs simultaneously.

A microscopic examination reveals the fact that the inflammation affects the tissues through the blood-vessels. Numberless round cells infiltrate the intima and adventitia to collect on the external surface and form the lines and layers of pus cells along their course. In the substance of the brain and cord beneath and about the vessels "proliferation of the nuclei in the neuroglia takes place, with swelling of the ganglion cells and granulo-fatty degeneration of the nerve fibres" (Eichhorst). Examination of the blood reveals the presence of hyperleucocytosis varying from 12,000 to 32,000 per cubic millimetre (Flexner and Barker). The polynuclear and neutrophile cells are the ones most increased; the number of eosinophile cells remains practically normal. Netter calls attention to the resemblance between the leucocytosis of cerebro-spinal meningitis and that of pneumonia, and suggests that the fact that the leucocytosis in cerebro-spinal meningitis is without prognostic value, such as it has in pneumonia, is probably to be explained by the fatal issue in cerebro-spinal meningitis being due to the organic changes in the nerve centres rather than to the infection itself. The presence of micrococci in the exudation has been mentioned already.

SYMPTOMATOLOGY.—The symptoms of cerebro-spinal meningitis naturally fall into two groups, those belonging to the general infection, and those belonging to the local lesion.

The period of incubation lasts from eight to ten days (Latimer). The period of invasion is very short. The onset of the disease is in the majority of cases sudden, with the impress of profound toxæmia. Prodromal symptoms exist in but five per cent. of cases (Ziemssen), and the symptoms of this period are too vague, in the absence of an epidemic, to establish a diagnosis. Malaise, headache, anorexia, nausea, chilliness, wandering pains precede the outbreak of the disease in a few cases. These are symptoms which may mean nothing or may serve as forerunners of any one of the acute infections. The disease dates from the initial chill or chilliness, and subsequent fever, with vomiting, headache, and stiffness of the neck. This chill may repeat itself several times in the course of the disease, more especially in the intermittent forms, and it signifies always a new invasion or advance of the disease. During and subsequent to the chill the temperature begins to rise, reaching 100° to 102° F., as a rule, by the second or third day of the disease. In foudroyant cases it may run up rapidly from the beginning of the disease, reaching a pre-agonal acme at even 108° F. (Wunderlich). Post-mortem elevations are not uncommon in bad cases. But even excessive elevation of temperature in cerebro-spinal meningitis may be followed by recovery. A remarkable case is reported by Christian (*Medical Record*, vol. lvi., No. 10), in which the temperature reached 118° F. on successive days. The patient recovered. On the other hand, some of the worst cases show little or no elevation of temperature at all (Hirsch and Ziemssen). In one case reported by Stokes the highest temperature recorded was 98.8° F. The characteristic of the temperature in this disease is irregularity. Cerebro-spinal meningitis shows an atypical temperature curve, a fact which distinguishes it at once from typhoid fever. Exacerbations and remissions occur so frequently in the course of the disease, even in the same day, as to baffle the most patient investigators. Ziemssen declares that few of the curves resemble each other, and Bäumler confirms this statement from his own observations. Wunderlich attempts to account for this irregularity by the successive complications on the part of the bronchi, lungs, intestines, serous membranes, etc., and Emminghaus appeals in explanation of it to the influence of œdema of the brain, basal lesions, affections of the cord, perhaps of a heat-regulating centre.

The pulse is increased in frequency as a rule. It is usually more full and strong at the beginning of the disease, and may number not more than 80 to 100 beats to the minute throughout its course. But the pulse is subject to the same deviations as the temperature, to which at times it seems to bear no relation. Tourdes and Ziemssen mention variations of 30 to 40 beats between observations at different times of the day, and every practitioner of experience has noticed fluctuations in the course of the same observation. In foudroyant cases the pulse may be increased to from 140 to 160 per minute, to become thready and imperceptible before the end of the disease. Abnormal slowness, it may be stated here, is much less frequent than in basilar meningitis. The irritation of the pulse-regulating centres in the brain, the changes in the substance of the heart, the poisoning of the blood, as well as the various complications of the disease, have all been invoked to account for the varying conditions of the pulse.

The respiration is affected in the same way. Many cases show no especial disturbance in frequency or rhythm, while others are characterized by extreme irregularity. Sighing respiration is very frequent in childhood, and arhythmia with dyspnœa is not uncommon at all ages. Leyden accounts for the Cheyne-Stokes respiration, sometimes observed in the later stages of the disease, by pressure on the medulla occasioned by œdema. This explanation is based upon the observation of this symptom in animals by Schiff, after the artificial induction of hemorrhage in the vicinity of the medulla. Reference has already been made to a preparatory nasal catarrh in this disease, and in this connection may be mentioned the arrest of the nasal secretion, catarrhus sicca, noticed among the prodromal manifestations by Summerell and Schuchardt.

The symptoms on the part of the digestive system belong among the cardinal manifestations of the disease, as vomiting ranks in significance along with the chill, headache, and opisthotonos. It is only the mildest cases which show no disturbance of the stomach. It ceases frequently in a few days, to reappear in bad cases, and to remain, at times, a more or less constant attendant of the disease. It is especially provoked by the ingestion of food, sometimes even of water (Schilizzi), or by rising in bed. The contents of the stomach, then mucus in quantity, are rejected, and later a yellowish-green fluid is regurgitated from the duodenum through an incontinent pylorus. Hart says of his cases (St. Barthol. Hosp. Rep., xii., p. 105, 1876) that vomiting occurred without retching, was constant in bad cases, in which it was always an ominous manifestation. As a rule, however, it is preceded or attended by great effort, with such energetic contraction of the abdominal muscles at times as to eject worms from the intestinal canal. Loss of appetite is characteristic of the disease, even in the absence of fever, when it is dependent probably upon irritation of the vagus (Eulenberg). Yet the very opposite condition, boulimia, has been noticed. Reich speaks of a case of progressive emaciation, notwithstanding a "voracious appetite" throughout, and Stillé observes that "in no other disease is the return of a good appetite and digestion so prompt and complete." Constipation is the rule in this disease, from inhibition of peristalsis through the influence of the sympathetic, and is obstinate to the action of laxatives; yet diarrhœa from gastric catarrh, or dysentery from catarrh of the colon, occurs exceptionally in the later course of the disease. In the worst cases stools are voided continuously from a paralyzed sphincter, while the abdomen loses its sunken shape to become tympanitic.

Ordinarily the urine is passed freely, and in normal quantity and character; exceptionally there is difficulty in its discharge and alteration in its composition. Thus, pain may be experienced in evacuating the bladder, or there may be anæsthesia to such degree as to permit great distention of this organ. Emminghaus speaks of pear-shaped tumors above the symphysis, and Reeve mentions the case of a woman who passed her urine "by time," having lost all sensation in the bladder. Any neglect on the part of the practitioner may lead thus to a troublesome cystitis. In the last stages of the disease there may be incontinence of urine as well as of fæces. With any reduction in the quantity, the color and specific gravity are naturally increased, but the most curious anomaly of the urine in this disease is an increased quantity in the face of fever. This paradoxical condition is accounted for by the pressure and destruction, from the exudation, of parts of the medulla. Resorption of these products during the stage of resolution may lead to irritation of the medulla, with polyuria or glycosuria. Albumin, usually in small quantity, is present in about one-third of the cases. As a rule the albuminuria is febrile in origin; acute nephritis was found by Friis in only three out of ninety-seven cases.

The skin shows the greatest variety of eruption of any one of the acute infections, with nothing peculiar or pathognomonic in any. A scarlatinous blush, more especially of the face, is very frequent in the first days of the disease, and a roseolar exanthem, more especially upon the trunk and extremities, frequently follows later. Hirsch speaks of spots resembling measles, Ziemssen mentions urticaria, Kamph erysipelatous maculæ, Grimshaw pemphigus, and Jenks bullæ, in individual cases. As to the petechiæ which have falsely named the disease, they are most frequently distinguished by their absence. Davis states that they were present in but one-third of the cases seen by him; Tourdes saw only three cases in the epidemic at Strasburg, and Stillé observed no eruption whatever in thirty-seven out of ninety-eight cases, in the epidemic at Philadelphia. "Neither Burdon Sanderson nor Wunderlich mentions petechiæ or vibices as occurring during life; and Hirsch, after noting their occasional presence, is obliged to draw upon American authors for an account of them" (Stillé). Yet bloody eruptions or extravasations do occur in this disease as frequently, but not more so, as in any acute infectious malady of equal gravity. Thus, in the first New England epidemic, and later in the outbreaks at Geneva, Dublin, and Naples, they were frequently present. Stokes and Banas speak of spots which coalesced over some portions of the body, "so as to cover a large extent of the skin, and render it completely black, as though it were wrapped in some dark shroud" (Stillé). Not infrequently the petechiæ or ecchymoses appear only post mortem (Day).

The only eruption which has any real significance in this disease is herpes. It begins usually as early as the third day of the disease, and may continue in renewed eruption throughout its course, or, as Hirsch remarks, weeks after full recovery. It shows itself first, as a rule, about the face, on the lips, nose, forehead, and neck, or may extend to the chest, abdomen, back, nates, and even the extremities. Pneumonia is, perhaps, the only disease which shows herpes in equal frequency, but the herpes of meningitis differs from that of pneumonia in having no prognostic value. In fact, Hirsch claims that a renewed outbreak rather signifies an exacerbation of the disease. Ziemssen is inclined to regard it as of trophoneurotic origin.

As in all the grave acute infections or septic maladies, cerebro-spinal meningitis is sometimes associated with affection of the joints. Jackson likens the articular swellings to attacks of gout, and Collins speaks of the swollen, red, and tender state of various joints, especially the knee, elbow, and wrist, and often also the smaller joints of the fingers and toes. Rinecker and Wunderlich observed this complication early in the disease, Salomon and Litten during its course, and Pfeiffer in the period of convalescence. While articular affections are rather rare in this disease, some epidemics, notably that in Greece, 1869, have been distinguished by their frequency.

Of the *symptoms produced by the local lesions*, pain in the head is among the most prominent. Headache, crushing as if produced by a vice, or boring as from the penetration of nails or screws, is, as has been stated, one of the initial signs, and it constitutes always one of the most obstinate and distressing features of the disease. Strong men cry aloud in the agony of headache, and young children show, on account of it, the peculiar wild, strange look attending excruciating pain, which finds utterance at times in the *cri hydrocephalique*. But the localization of the pain does not of necessity localize the seat of the disease, nor does its intensity bespeak its gravity, signs which prove it to be partly due to the septic element. Fortunately, it is subject to intermissions or remissions in the course of the disease, and not infrequently it disappears altogether. The other signs of the disease may then still remain in force, though cessation of headache may be usually regarded as one of the most favorable signs in prognosis. Warning should be entered here, however, against that ominous arrest of headache, along with a general euphora, which sometimes immediately precedes the end. Vertigo may be associated with the headache, to greatly aggravate the sufferings of the patient by compelling the continued observance of the recumbent posture. Tourdes speaks of cases in which the giddiness was so intense as to cause patients to whirl and fall, unable to rise again. Such cases excite suspicion of implication of the semicircular canals.

Pain of a similar character, indescribable in its intensity, is also felt in other parts of the body, in the spinal column (rachialgia), in the extremities, or anywhere upon the surface in the course of the spinal nerves. Usually such pain is paroxysmal, stabbing, fulgurant, agonizing. It shoots out from the posterior nerve roots of the spinal cord, where the local lesion, as determined by gravity, is most intense, and carries with it sickening sensations of præcordial depression.

A more characteristic, though less frequent, sign of cerebro-spinal meningitis is hyperæsthesia of the surface. It is commonly absent altogether in the lighter or abortive forms, and may not show itself throughout the short course of the foudroyant forms, but it is quite constant, at least in the earlier days of the disease, in cases of average intensity. It is first seen, as a rule, in the lower extremities, to which it may remain confined; next in the upper extremities, and lastly in the face and head. Like the pain described it may undergo remissions and exacerbations, may disappear to recur later, or may last over, in regions, to the period of convalescence. When present it adds a peculiar poignancy to the suffering of the patient, who watches with anxious eyes every movement about the room. In aggravated cases it is manifest also during sleep, and even the stupor of coma does not entirely annul it. In such cases it interferes with, or even entirely prevents, an examination of the patient, which, however, may be unnecessary, as with the history and superficial inspection it frequently declares the disease. Hirsch, Fraentzel, and Ziemssen unite in saying that it is often absent throughout the whole course of the malady.

Opisthotonos stands in the foreground in the semeiology of this disease. It is rare that some degree of rigidity in the back of the neck is not present, though Burdon Sanderson declares that in the Prussian epidemic, 1864–65, there were many cases in which there was no stiffness or retraction of the muscles. In the lightest cases there is simply a sense of increased resistance on attempts at flexion of the head upon the chest—a valuable point in differential diagnosis—or a slight degree of tenderness to pressure upon the cervical vertebræ. In most severe cases rigidity is marked, with retraction of the entire head, to such degree at times as to give rise to extreme mechanical dysphagia. Leyden speaks of cases in which the head was bent back at a right angle to the spine, and Gordon mentions an instance in which, in addition to this deformity, the spine presented "a most wonderful uniform curve concave backward." The most striking illustration of the degree to which this extension may occur was reported by Neville Hart (St. Barthol. Hosp. Reports, xii., p. 105, 1876), in a case in which the pressure of the occiput caused a slough between the scapulæ. In the experience of this author the degree of opisthotonos corresponded with the gravity of the disease. Not infrequently the rigidity extends lower in the vertebral column, as in Gordon's case just mentioned. Thus Jansen mentions an instance where the whole body could be lifted rigid with the hand behind the occiput, and Ziemssen and Merkel report cases of "orthotonos" in which attempts to flex the head pushed the body like a statue to the foot of the bed. With the other symptoms mentioned this condition may disappear, to reappear in greater or less degree, undergo fluctuations throughout the disease, continue to the fatal end—as long in one case as forty-nine days,—or remain in some degree until full recovery. Ziemssen speaks of convalescents going about with rigid spines, and cases are reported in which the condition lasted throughout life. Usually the retraction is symmetrical, as pleurosthotonos is very rare. The rigidity is due to tonic contraction of the deep muscles of the neck, the splenii; the superficial muscles, the trapezii, remaining unaffected. It is easy to understand it in the presence of the abundant exudation about the medulla oblongata, but the absence of it in the presence of the same conditions remains as yet inexplicable.

Besides these tonic, clonic spasms may occur in the muscles of the face, trunk, or extremities, as mere fibrillar twitchings or veritable convulsions. Children are much more frequently affected in this way than adults, and the spasms occur more often in the graver than in the lighter cases. Sometimes the case begins with a well-marked epileptiform convulsion, and cases, as in the epidemic at Dublin, have been characterized by their persistence throughout the disease. The convulsions may be limited to one side of the body, and Netter reports a case in which the convulsive paroxysms were confined to one side of the face. Attempts at changing the posture, or agitation of the patient in any way, as by sounds or the approach of light, are often the exciting causes. Yet grave as is this complication in adults, it is by no means fatal of necessity. Thus Stillé records a case, cited from Vienna, in which "convulsions occurred repeatedly during the first two days, and less frequently during the two following days, but the patient ultimately recovered." In the case of a young lady under the observation of Whittaker, clonic convulsions of the upper extremities existed continuously for three days and nights, and were only stilled finally by narcotic doses of opium. This patient escaped with life, but with lesions that left it of little value. As a sub-variety of convulsions may be mentioned tremor, which occurs exceptionally, more especially in children, and jactitation, which may occur at any time, more especially in the graver cases, and more frequently toward the end. The tonic and clonic spasms, expressions of the stage of irritation, give place in time to paralyses as evidence of destructive change. Ptosis, paralytic strabismus, and paralysis of the facial nerve may be thus manifestations of the later period of the disease, or may be associated with hemiplegia as evidence of central lesion. Emminghaus quotes in this connection from Leyden, who saw in several cases paralysis supervene in the contracted muscles of the neck. Thus also hyperæsthesia may eventuate in anæsthesia to such degree as to permit the penetration of a pin. Aphasia has been observed by Leyden and Netter.

Of the special senses, besides that of touch, the senses of vision and hearing suffer most. Corresponding to the hyperæsthesia or hyperalgesia of the surface of the body is photophobia, to such degree, as a rule, as to necessitate the darkening of the chamber and the avoidance of artificial light. Graver lesions than this functional disturbance, conjunctivitis, iritis, irido-choroiditis, neuritis, atrophy of the optic nerve, even panophthalmitis, may occur in the course of the disease. The same exaltation of sensibility affects the ear with even greater distress, because offence in this regard is less preventable. Tinnitus aurium is frequent. Suppurative processes in the middle and internal ear, perforation of the membranes, atrophic changes, are among the graver affections of this organ, to be mentioned later among the complications and sequelæ. Loss of the sense of smell on one side was first observed by Ames. Alteration of the sense of taste has been reported by Corbin.

Delirium is quite uniformly present at some stage of this disease. It sets in, as a rule, on the second or third day, to vary in degree, coinciding often with the fever or the headache, or to be replaced by stupor, apathy, or coma at various periods of the disease. Low forms of delirium are constantly associated with sleeplessness, or incessant mutterings, the so-called coma vigil, alternate with outbreaks of maniacal excitement. Illusions and hallucinations are, though rare, sometimes encountered, and permanent impairment of the intellect may result. Yet long-continued stupor is quite exceptional in meningitis, though complete oblivion of every incident of the attack has been noticed not infrequently, even when the symptoms on the part of the nervous system have been of light degree.

COMPLICATIONS AND SEQUELÆ.—With the elements of a general inflammation of the membranes of the brain and spinal cord, and the implication of the nerves irradiating thence over the body, together with affection also of the substance of these organs, superadded to a general poisoning of the blood, it is not to be wondered at that complications and sequelæ of various kinds occur in this disease. Among the most frequent and serious of these complications are *catarrhal pneumonia* and *croupous pneumonia*. Of these affections catarrhal pneumonia, or broncho-pneumonia, is most frequently encountered in children, and, if developed as a secondary affection, readily undergoes, according to Ziemssen, favorable resolution. But croupous pneumonia has a much more serious prognosis. It occurs more frequently in certain epidemics —fifteen times in the Erlangen epidemic of 1866 to 1872— and develops by predilection in the later periods of the outbreak of the disease. But Jürgensen reports of his cases that the relation of the two diseases was in three cases just the reverse, as the meningitis supervened upon or followed the pneumonia. This author calls attention to the great difficulty of diagnosis in these cases when opisthotonos happens to be absent. In this connection Maurer points to the arching of the fontanels in young infants as indicative of increased intracranial pressure, a sign of great value in a doubtful case. Schilizzi at Aigues-Mortes, Tourdes at Strasburg, Levy at Paris, and Laveran at Metz, have all found serous and sero-purulent exudations in the pleural cavity as complications of this disease. Eichhorst emphasizes the frequency with which affections of the throat occur as not sufficiently remarked hitherto, and Pfeiffer found parotitis present in a number of his cases at Thüringen.

Peripheral or multiple neuritis has been observed in some cases (C. K. Mills, *Medical News*, March 3d, 1888). In the retrogressive changes which occur during and after the period of resolution, various thickenings, thrombotic occlusions, or permanent hyperæmias may be left behind. Thus it is not surprising to learn that headaches sometimes remain for years, or for life, or that paralysis of various muscles, especially those supplied by cranial nerves, the abducens, oculomotor, and facial, develop during the disease or after it has run its course. Perhaps the most deplorable, if not the most dangerous, damage is done in this way to the organs of sight and hearing. Hyperæmia of the conjunctivæ, "redness of the eyes," with irregularity of the pupils, and photophobia are to be noticed, as a rule, at the onset of the disease, and affections of the cornea, synechiæ, opacities of the lens, iriditis, etc., have been mentioned in its course. Fish spoke of cases announced by blindness, to be followed later by symptoms on the part of the spine, and though the amaurosis was in his cases always temporary, examples of permanent loss of sight are abundantly recorded. Rudnew claims that a microscopic examination reveals suppurative inflammation of the uveal tract, as a rule, in this disease. The affection begins in the capillaries of the choroid and proceeds to invade its entire structure.

The ear is affected, as stated, in both its middle and internal parts. In a case reported by Ziemssen the pain of an otitis media began as late as the twenty-fifth day of the disease, and perforation with the discharge of pus did not occur until the thirty-sixth day. Heller and Lucæ and Moos describe cases in which the trunk of the auditory nerve was embedded in pus, with hyperæmia of the neurilemma, suppurative inflammation of the cavity of the drum, hemorrhage and pus in the membranous labyrinth. Per contra, Ziemssen has seen cases in which the floor of the fourth ventricle was "macerated by pus, and the auditory nerve, together with the facial nerves, completely surrounded by the purulent exudation, without the occurrence of deafness during life." But cerebro-spinal meningitis is one of the most common causes of deafness, perhaps the most common cause of all diseases affecting the internal ear. For in the vast majority of cases the affection is bilateral and permanent. Knapp states that in every one of thirty-nine cases the deafness was bilateral, and, "with the exception of two cases of faint perception of sound, complete." Should this complication occur in the earliest years of life the patient is not only deaf but also dumb. The Bamberg Deaf and Dumb Asylum contained, April, 1874, forty-two pupils —deaf-mutes, without exception, from cerebro-spinal meningitis; and of the thirty-two inmates of a similar institution at Nuremberg, twenty-two were victims of this disease. Moos mentions further that one-half of his cases that recovered from the disease with some impairment of hearing showed also disorder in maintaining their equilibrium.

That processes of cicatricial contraction, by thickening and shrivelling the pia and obliterating its plexuses of vessels, may lead eventually to chronic hydrocephalus, or that these accidents with the deeper lesions in the substance of the brain and cord may beget aphasia, anarthria, impairment of memory or other faculties of the intellect up to complete imbecility, may readily be inferred. One case illustrative of the extent of damage that may be inflicted by this disease upon a patient who barely escaped with life may be cited from the graphic descriptions of Gordon. This was a case in which the patient recovered from all the acute symptoms, but gradually, in fifty-eight days after the invasion of the disease, passed into a state of almost organic life. "He ate, drank, and slept well; he passed solid fæces and urine without giving any notice, yet evidently not unconsciously; he was excessively emaciated, and there was a peculiar mouse-like smell from him; he seemed to understand what was said to him, but he could not answer; he never called for anything; his breathing was rather slow; his pulse 120; his heart acting with a peculiar strong jerking motion; his eye was quite well as also his knee (he had suffered from ulceration of the right cornea and immense effusion into the right knee-joint); he could draw his legs and arms up to him; but he could not use his hands at all."

DURATION.—Cerebro-spinal meningitis has no definite duration. Hirsch says of it that it may last from a few hours to several months. The first period applies to the foudroyant cases, in which patients are killed as by a stroke, the last to the cases with complications or sequelæ, which may indeed prolong the disease indefinitely. Gordon's shortest case was one of five hours' duration, and Jewell records a case of death in three hours and a half after seizure. These are, of course, most extreme and exceptional cases. Clymer states that more than one-half the deaths happen as early as from the second to the fifth day. This author quotes also from Parkes, who found the duration of the disease in 66 of 95 cases, five days or less; in 1, eight days; in 28, eight days or over. Abortive forms terminate in resolution in from three to five days, foudroyant forms, with rare exceptions, in death within three days, and intermittent and average forms in one or the other way, barring complications and sequelæ, in from one to three weeks. Relapses are not common. Second attacks are rare, but such cases have been reported by Boudin, North, Warschauer, Hermann, and Kober.

Diagnosis.—In the presence of an epidemic of the disease the diagnosis of cerebro-spinal meningitis is sufficiently easy. The existence of cases in the vicinity prepares the practitioner for new attacks. Cases which are affected with, or more especially quickly succumb to, any disease with predominant nervous symptoms should excite the suspicion of the physician in this direction. Sporadic cases, however isolated in space or time, are likewise readily recognized in the presence, in sufficient number, of the symptoms peculiar to the disease. The sudden seizure, often in the midst of health, with chill, vomiting, and prostration, followed by opisthotonos, hyperæsthesia, herpes, irregular pulse, constipation, constitutes an array of symptoms that belong to no other disease. Unfortunately for the diagnosis many cases deviate from the regular type in essential particulars, more especially in the absence of characteristic signs, to such degree as to make the diagnosis difficult or at times impossible. Foudroyant cases differ most widely by the predominance of the symptoms of blood poisoning which are common to all the grave acute affections. Light is sometimes thrown upon these cases by the consideration of the season of the year, the age of the patient, the existence of other cases more pronounced, or, if equally obscure, by the exclusion of simulating maladies or accidents. Thus a meningitis from trauma, insolation, or otitis should be discovered by the history and inspection of a case; or occurring in the course of scarlatina, pneumonia, septicæmia, it should be eliminated by the presence of signs characteristic of these affections.

The Kernig Sign.—Kernig, of St. Petersburg (1882), reported as characteristic of meningitis that when the hip is flexed, as when the patient is in the sitting posture, contraction of the flexors of the leg prevents full extension of the knee without undue force, so that as a rule the limb may not be extended beyond 135° and sometimes not beyond a right angle. With the hip extended, as when the patient is lying down or standing upright, extension of the knee readily occurs. Kernig's observation has been confirmed by numerous observers, among them Bull, Henoch, Blümm, Friis, Netter, Osler, and the writers. It has been suggested that an explanation of the phenomena may be found in a peculiar irritability of the roots of the nerves, in consequence of inflammation of the meninges, and that the irritability of the sacral roots is increased when these nerves are put upon the stretch by flexion of the hip, so that there occurs reflex contraction of the flexors upon attempting to extend the knee with the hip flexed. But such reflex contraction of the flexors does not take place with the hip in extension. For the production of the Kernig sign, it is necessary that the meningitis involve the spinal membranes. Thus the sign is found in tuberculous and simple meningitis as well as in cerebro-spinal meningitis. Kernig reported finding the sign present in 15 cases of acute meningitis, which included 13 cases of epidemic cerebro-spinal meningitis, 1 of tuberculous meningitis, and 1 of suppurative meningitis. The diagnosis was confirmed by autopsy in 8 cases. Netter found the sign present in 45 cases of meningitis. But the Kernig sign is not always present in meningitis. Thus, Henoch, Friis, and Netter have observed cases of meningitis in which the Kernig sign was absent. In general, the sign is found in about 90 per cent. of cases. Netter found the sign in 45 out of 50 cases; Friis in 53 out of 60 cases. It has generally been held that the sign is present only in meningitis, but one of the writers found the sign well marked in a case of scarlet fever, during the period of invasion, without other evidence of meningitis.

The lumbar puncture (Quincke) often furnishes much more exact information, in that it may reveal the specific infectious agent causing the meningitis. The puncture is made between the spinous processes of the third and fourth lumbar vertebræ (Quincke) or between the fifth lumbar and the first sacral vertebra (Chipault, Netter), so as to withdraw the cerebro-spinal fluid from the lower cul-de-sac of the dura mater surrounding the cauda equina. The patient is placed upon the side, with the legs flexed upon the body and the body inclined well forward (Quincke), or in the sitting posture inclined forward (Fürbringer, Netter). The fluid may be withdrawn through a fine trocar, aspirating needle, or an ordinary hypodermatic needle. The puncture is made in children in the median line immediately above the spinous process, to a depth of about 2 cm. In adults the puncture is better made at the level of the lower border of the spinous process and 5 to 10 mm. outside of the median line, to avoid the thick ligaments, in a direction from above downward, so as to puncture the membranes in the median line, and to a depth of 5 to 7 cm. The puncture should be made under strict aseptic precautions, and the fluid should be removed slowly. When properly made, the operation is practically without danger, and is of great diagnostic importance since it will in very many cases reveal the specific infectious agent. The cerebro-spinal fluid is cloudy and purulent and contains micro-organisms both intra- and extra-cellular. Albumin is usually present in the cerebro-spinal fluid in a proportion varying from .1 per cent. to .4 per cent. Sometimes no fluid may be obtained upon puncture, and sometimes the fluid that is obtained is perfectly clear and sterile, even in the presence of meningitis, especially in cases that have lasted for some days. A case of tuberculous meningitis may no longer present tubercle bacilli, or only in such small numbers as to be detected with difficulty. Again, such cases may present the meningococcus as the result of a mixed infection. Thus the lumbar puncture is not an absolute criterion in the differentiation between tuberculous and other forms of meningitis.

Examination of the blood has revealed the meningococcus (Netter), and the pneumococcus (Bozzolo, Netter). In making such examinations, .25–.50 c.c. of blood should be used. Rarely the specific infectious agent may be obtained from the urine or sputum.

Of more value is the bacteriological examination of the nasal secretion. Thus Scherer found the Diplococcus intracellularis in eighteen cases of cerebro-spinal meningitis, while in fifty other cases this organism was found only two times. One of these latter cases had a coryza following the disinfection of a room in which a patient died of meningitis; and there was some doubt about the diagnosis of the second case, which may have been one of meningitis but had been treated for typhoid fever complicated by ocular paralysis. However, too much importance should not be ascribed to the result of the examination of the nasal secretion, since the meningococcus has been found in the nasal secretion of healthy individuals by Heubner, and the pneumococcus by Netter and many other observers.

Typhoid fever distinguishes itself by the fact that it usually spares the period of earliest youth, that its onset is insidious, that it is attended with diarrhœa and distention of the abdomen, that it often shows a rose-colored eruption, has a constant high pulse, a typical temperature curve, and a definite duration. Moreover, typhoid fever almost never shows herpes, and almost always shows enlargement of the spleen. The diazo reaction, commonly present in typhoid fever, is absent in meningitis. The presence of the reaction in meningitis indicates an unfavorable prognosis. The Widal test is positive in typhoid fever, and negative in meningitis, except when the meningitis is due to infection by the typhoid bacillus. Further evidence would be furnished by the Kernig sign, which is present in meningitis and absent in typhoid fever, and by lumbar puncture. Malarial fever is marked by its preference for certain regions and certain seasons of the year. Periodicity is the criterion of malaria, and though this factor is simulated in the intermittent cases of meningitis it is never so precise. Reeve says the early vomiting was the key to the diagnosis of his first cases of meningitis. Whatever doubt may exist at first is quickly dissipated by finding the plasmodium malariæ in the blood or by the administration of quinine in sufficient dose. Tetanus is eliminated by its trismus, and hydrophobia by its characteristic paroxysms of inspiratory spasm. Tuberculous meningitis rarely shows symptoms on the part of the spinal cord, though opisthotonos and hyperæsthesia are not uncommon in this disease. Tuberculous meningitis is nearly confined to childhood. In the great majority of cases its victims are of tuberculous parentage or stock. It is not affected by the season of the year. It distinguishes itself especially by its long prodromal stage, by its periods of reduction of temperature and retardation of pulse, by the occasional signs of tuberculosis elsewhere, in the lungs or intestines, externally (scrofulosis) upon the skin, or possibly in the bottom of the eye. Netter believes that confusion has often arisen in the differentiation from influenza, and that many cases of "grippal meningitis" are really cases of cerebro-spinal meningitis.

Prognosis and Mortality.—The prognosis of this disease is always grave. The factor of most importance in its determination is the type of the disease. Foudroyant cases perish with very rare exceptions; abortive forms recover with few exceptions, and average cases survive and succumb in about equal number. The character of the epidemic is the next consideration. Certain outbreaks are distinguished by their mildness, as are others by malignancy. Thus Lowe and Wooley (London *Lancet*, June 26th and August 3d, 1867) report that not a single case died in the outbreak at Bardney, in Lincolnshire, England, in January and February, 1867, though the disease was characterized by "severe rigors, tetanic convulsions, intense neuralgic pain in the head and upper part of the trunk, increased sensitiveness of the surface, obstinate vomiting, restlessness, and in one instance, at least, by a dark purple eruption" (Hartshorne's "Reynolds," vol. i., p. 308). On the other hand, Wunderlich, Stonone, and others, give instances in which not a single case recovered. Young reports of the attack at Granada, Miss., that every one of the 35 cases perished, and the same fatality attended the first outbreak of the disease at Memphis, Tenn. Between these extremes is every grade of gravity in different attacks. It is also true of this, as of most of the acute affections, that the first cases are most severe. The epidemic grows feebler, as a rule, with the gradual exhaustion of its most fertile soil. Individual considerations follow next. The prognosis is more grave in infancy and childhood than in adolescence and maturity. The ratio of mortality falls from 75 per cent. in children under one year of age to 53.5 per cent. in later childhood, and 35 per cent. in adolescence. Not to burden this section with a useless array of figures from different epidemics—useless because inapplicable to individual cases—the general statement of Hirsch may be given as indicating the average mortality of this disease. Of 15,632 cases analyzed by this indefatigable statistician, 5,734 terminated fatally. Thus the average ratio of mortality of this disease, under all conditions, is given at 37 per cent. The influence of "bad hygiene" in aggravating the prognosis is too patent to require mention. Of more importance are the signs which prognosticate the result in individual cases. It may be stated, as a rule of this, as of all the acute infections, that a severe onset indicates a grave case. Thus a high fever at the start, obstinate vomiting, marked opisthotonos, early convulsions, are signs of ominous import. As one-half the deaths happen before the fifth day (Clymer), a case which survives the first week has a more favorable outlook. The first three or four days are attended with the greatest anxiety. "Every day passed after the seventh day renders recovery more and more probable" (Loomis). Typhoid symptoms at any stage of the disease imprint upon it an unfavorable prognosis. Arching of the great fontanel, as indicative of intracranial œdema and exudation, is a very bad sign. Almost all such cases end fatally (Maurer). A return of headache and vertigo which has disappeared, especially if associated with vomiting and convulsions, evidences of consecutive hydrocephalus, is likewise ominous (Ziemssen). Yet secondary hydrocephalus is not absolutely hopeless, as Ziemssen saw "some cases in which a complete, and others in which an incomplete, recovery took place." Profuse sweats, with cold surface, are characteristic of a fatal issue (Hirsch). The persistence, after recovery from the disease, of anorexia, debility, and emaciation, perhaps with diarrhœa, gives a poor outlook, especially for children (Emminghaus). A sudden high elevation of temperature, or hyperpyrexia, after a chill in a previously apyretic case, means a complication, and not a fatal issue, but a hyperpyrexia without chill, and with a profuse sweat, is pre-agonic (Immermann.)

Prophylaxis.—Occasional instances are reported which would seem to prove the possibility of cerebro-spinal meningitis being a contagious infection, as by Niemeyer, Fraentzel, Hirsch, Stokes, Simon, and Ziemssen. Cases should be treated as if contagion were possible. Flint suggests that the "removal of persons from without the area in which the disease prevails is desirable." Inasmuch as certain barracks, asylums, tenement-houses, schools, etc., become at times centres or depots of the disease, these institutions should be thoroughly cleansed and ventilated, or, what is better still, vacated or closed. For while it is admitted that "crowd-poisoning," with all the defective hygiene the term implies, cannot develop the disease, it is as fully acknowledged that these circumstances eminently favor its spread. At least this was the condition, in aggravated degree, which attended its most extensive outbreak in Dantzic in 1865, when the disease prevailed, according to Hirsch, "exactly in that season of the year in which, on account of inclement weather, many individuals were crowded together into small and dirty rooms, kept constantly closed by their occupants, and from which all ventilation was excluded, and in which the before-mentioned unfavorable hygienic conditions (dampness, great filth, and an atmosphere loaded with putrid emanations) were extremely perceptible." While it is not necessary that the physicians and attendants shall take the same precautions with their own *personnel* as in many of the contagious diseases, yet in the light of existing knowledge full disinfection should follow post-mortem examinations, and short and limited contact should be had with the bodies of the dead. During the prevalence of an epidemic caution should be enjoined against excessive muscular effort, the unrestrained excesses of childhood, for example, against exposure to cold and wet, or excessive mental labor.

Therapy.—A patient affected with this disease should lie upon a comfortable bed, not too hot, in a spacious, continuously ventilated room, the windows of which can be darkened if necessary while they still admit the air, as remote from the street with its offensive sounds as may be. The temperature of the room should be regulated, with a thermometer near the head of the bed, at 65° F., by an open fire, preferably in a grate. The physician and the necessary attendants should be the sole visitors. Quiet should reign supreme. In no other disease is continuous or officious ministration so meddlesome and mischievous. Even cleanliness or a more comfortable posture must be sacrificed at times to peace of mind. The diet is to be simple and light at first, but as nutritious as possible with returning health: beef-tea palatably made, soups of any kind, milk if it does not increase constipation, scraped raw meat, with a little salt, and gruels, if not distasteful. Plain water, seltzer water, Apollinaris, or any simple carbonated drink, should be proffered at proper intervals, without over-solicitation or any anxiety should everything be refused. With the beginning subsidence of the disease an egg may be dropped into the soup, or sweetbreads, fish, the white meat of fowl may for a few days preface the more solid meats.

Especial attention is to be paid to the bladder. The soft catheter, thoroughly cleansed, warmed above the heat of the body, and greased with pure vaseline, brings this organ, when refractory, under control. Constipation is overcome with calomel, two to ten grains, or castor oil, in preference to an enema, which causes too much disturbance.

The treatment proper is purely symptomatic, and has reference to the two sets of symptoms, general and local. Of these the symptoms produced by the local lesions—pain, opisthotonos, hyperæsthesia—assume prominence in the great majority of cases. For the relief of these symptoms no remedy equals in value opium. Opium is the "sheet-anchor" in the treatment of cerebro-spinal meningitis. It acts solely by its anodyne influence. It protects, by obtunding, the nervous system until the force of the poison is spent. Surprising amounts of the drug may be given in this disease without narcotic effects. Thus Steiner often gave ten grains at a dose in cases of severe convulsions without producing stupor; Chauffard, three to fifteen grains; and Boudin, seven to fifteen grains at first, and later, one to two grains every hour before soporific effects were produced. Stillé was in the habit, he says, of prescribing one grain every hour in very severe, and every two hours in moderately severe cases, without inducing even an approach to narcotism in any case. "Under the influence of the medicine the pain and spasms subsided, the skin grew warmer and the pulse fuller, and the entire condition of the patient more hopeful." When quick effects are to be had, or when the drug is rejected by the stomach, resort will be had, of course, to the hypodermatic use of morphine. Ziemssen gives expression to an experience made by every practitioner with this disease when he says that morphine is, without doubt, "indispensable" in its treatment. But "*medicus systematicus periculosissimus vir*"; that would be indeed a routine physician who would prescribe opium indiscriminately in every case.

The use of the warm bath in cerebro-spinal meningitis was introduced by Aufrecht, of Magdeburg (1894), with the report of a single case cured by daily warm baths. Voroshilsky, of Odessa (1895), employed the warm baths three times a day in sessions of ten minutes at a temperature of 104° F. with good results in two cases. These observations were confirmed by Borling and Kellmeyer, of St. Petersburg, and Steckel, of Vienna, and more recently by Netter, who reports six cases treated with warm baths repeated every three or four hours, with no mortality. This experience leads Netter to declare that the warm bath is "a specific method of treatment of cerebro-spinal meningitis."

Venesection in this disease belongs to history, or is only at most to be practised in relief of intracranial pressure, as in apoplexy, in the most sthenic cases, and in these cases the same results may often be effected by milder means, as by purgatives, calomel, and jalap. But local blood-letting by cups along the spine, or by leeches behind the ears, may often relieve the headache and unrest. Cold in the form of bags of ice to the head or along the spine is of great value when the period of excitability, hyperæsthesia, and jactitation may have given place to the state of sopor and indifference. Radcliffe claims that "the application of cold to the head and spine either by means of ice or a freezing mixture in Esmarch's (or Chapman's) india-rubber bags, has furnished by far the most satisfactory results of all direct treatment."

Vomiting is best relieved by ice, champagne, effervescent drinks, milk and lime water, bismuth, soda, carbolic acid, or creosote. No drug equals in efficacy sips of water excessively hot.

Hiccough is often brought under control by the same means prescribed for vomiting, by the administration of a few drops of the oil of cajeput, or by clysters of sodium bromide. More obstinate cases of either vomiting or singultus call for the subcutaneous use of morphine.

The hypodermatic injection of an aqueous solution of corrosive sublimate along the spinal column has been recommended by Angyan in daily doses of 1. cgm. for adults and .5 cgm. for children, continued until the rigidity disappears. Angyan reports thirty cases treated in this way with twenty-one recoveries.

Kay lauds the virtue of permanganate of potassium in grain-to-the-ounce solution, a tablespoonful every hour, and reports four cases with three recoveries.

It is useless to encumber space in a work of this kind with more than a mention of other remedies lauded in the treatment of this disease. As to quinine, which was recommended by the committee of the American Medical Association, it is now admitted to be of no avail whatever, except in antipyresis, a call which is seldom made in this disease. But in the exceptional cases, in which high fever does occur, quinine in scruple dose, salicylic acid or antipyrin in double the quantity, are more valuable than the cold bath, because of the commotion created by the bath. Blisters, moxa, ferrum candens, are brutal assaults in the height of the disease, but may be justifiable in the treatment of sequelæ. The same remarks apply to the use of electricity. Ergot, iodine, physostigma, mercury, the benzoates, the bromides (which may be substituted for opium in a very mild case), other anodynes, belladonna, with a host of other remedies, have been recommended on theoretical grounds, or praised as specifics by practitioners of the "experience" school, who for the most part remain untrained to eliminate "the personal equation," but none of them stands the test of time.

Lumbar puncture has been recommended in treatment, but is not at the present time believed to be curative, although after the withdrawal of a small amount of fluid there is often marked improvement of the symptoms.

The various symptoms presented in the course of the disease are treated precisely as are the same symptoms in any acute infection, after methods mentioned in detail in this work in the history of diseases in which these symptoms assume especial prominence.

James T. Whittaker.
George E. Malsbary.

CERIUM.—A single salt, only, of cerium is official in the United States Pharmacopœia, namely, *cerous oxalate*, entitled *Cerii Oxalas*, Cerium Oxalate: formula, $Ce_2(C_2O_4)_3, 9H_2O$. This salt is "a white, granular powder, without odor or taste, and permanent in the air. Insoluble in water, alcohol, ether, or in solutions of potassium or sodium hydrate; soluble in diluted sulphuric or hydrochloric acid" (U. S. P.). In effect cerous oxalate most nearly resembles the insoluble bismuth compounds, being, from its insolubility, devoid of active properties, but yet like many other insoluble metallic powders, having a power to allay local nervous irritability. This influence is utilized to combat reflex nausea and vomiting, especially the vomiting of pregnancy, and also to repress irritative dry coughs. In this latter application, when successful, the present drug has the advantage over the ordinary run of cough medicines of not disordering the stomach, but, on the contrary, of tending to quell any irritation of that organ. The oxalate may be given in doses of from .30 to .65 gm. (gr. v. to x.) several times a day, best taken dry upon the tongue. Such doses may be kept up for a number of days in succession with no other effect than causing, at first, a little dryness of the mouth. For cough, the medicine should be persisted in even if, as may happen, there be no benefit for the first two or three days; and especially should doses be given on the empty stomach early in the morning and late at night.*

Edward Curtis.

CERVICAL FISTULA. See *Teratology.*

CERVICO-BRACHIAL NEURALGIA. See *Neuralgia.*

CERVICO-OCCIPITAL NEURALGIA. See *Neuralgia.*

CESTODA.†—The branch or Phylum Platyhelminthes, commonly known as the Flat Worms, is characterized by a bilaterally symmetrical body somewhat flattened dorso-ventrally and usually elongate, by the mass of parenchymatous tissue which fills all the spaces of the body, by the absence of any true body cavity, by a protonephridial excretory system, and by the complicated sexual apparatus which with rare exceptions is hermaphroditic, and which produces so called compound eggs. Among the most prominent orders of the branch are the Trematoda or Flukes (*q. v.*) and the Cestoda or Tapeworms to be considered here.

The order Cestoda includes a large number of forms which manifest considerable differences in anatomical detail, but are comparatively uniform in general appearance and structure. The small group of Cestodaria, or Monozoa, which differ from all others in possessing but a single set of reproductive organs, and consequently but a single segment in the body, is included by some investigators in the order under consideration, but by others placed intermediate between the trematodes and the cestodes, forming as it undoubtedly does a group transitional from the one order to the other. The species of Cestodaria are, however, rare and infest the lower animals, so that they will not be discussed here.

In the Cestoda *s. str.* the body is characteristically ribbon-like and divided into "links," segments, or proglottides. In most cases, including all the tapeworms of man, the segmentation is evident externally. At the posterior end of the chain the proglottides are larger and more distinct, and often so loosely attached as to separate from the series under the slightest disturbance. In fact such separation takes place normally as the segments become ripe. Toward the other end of the chain the proglottides grow gradually smaller and less distinct until near the anterior end it is usual to find a short region, the neck, in which no trace of segmentation is visible. The anterior end has the form of a bulbous swelling, known as the head or scolex (Fig. 1203), on which are borne the organs of fixation. The latter are either suckers, hooks, or both, and the suckers may be either elongate grooves or bothridia, cup-shaped hollows or acetabula, or, as in some marine tapeworms, of a folded form which is much more complicated.

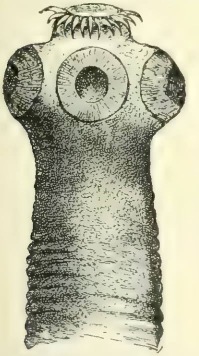

FIG. 1203. Anterior End of *Tænia solium*, Showing Scolex, Suckers, Rostellum with Hooks, and Neck. × 45.

At the apex of the head is found in the Tæniadæ a muscular organ, the rostellum which bears the hooks, usually in one or more annular rows. In form and degree of development the rostellum is a very variable organ; at the one extreme in *Tænia saginata* it is reduced to a small muscular sucking apparatus, often spoken of as the apical or fifth sucker of that species, while in other forms it is powerfully developed and capable of extension or retraction into a pocket at the apex of the scolex. It is a valuable feature in the distinction of various species.

In the head one finds the central nervous system in the form of a bilateral ganglionic mass with one or two ring-like commissures from which nerves are given off directly to the suckers and rostellum, and from which the longitudinal nerve trunks pass backward throughout the length of the chain. Three of these trunks, the main lateral nerve (Fig. 1204, *ln*) and two minor (*ln'*) are grouped together on each side of the proglottis, while the two dorsal and the two ventral longitudinal nerves (*ln''*) are located nearer the median line. The various longitudinal trunks are connected by commissures which at stated intervals pass around the proglottis; they also give off branches by which the various organs are innervated.

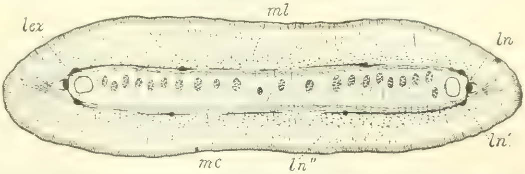

FIG. 1204. Transection of Proglottis of *Tænia solium*, Somewhat Diagrammatic. *ln*, Main lateral nerve; *ln'*, accessory lateral nerve; *ln''*, ventral longitudinal nerve; *lex*, longitudinal excretory canal; *ml*, longitudinal body muscles; *mc*, transverse body muscles. The section is represented as having cut one of the ring commissures throughout nearly its entire extent. (Original.)

Near the lateral nerve trunks are located the main longitudinal canals (*lex*) of the excretory system which originate in an irregular network in the head and from which are given off numerous branches often in the form of a network of fine vessels in each proglottis. In many forms a prominent transverse canal near the posterior margin of each proglottis joins the longitudinal canals (*cf.* Fig. 1205, *C*). Terminating the finer canals of this system are found the characteristic flame cells which are peculiar to this type of excretory system.

A cross section of a proglottis (Fig. 1204) shows the various layers of which it is composed. Externally the cuticula, a resistant, elastic membrane, covers the body and is reflected a short distance inward at the various external orifices. The older view, by virtue of which an epithelium is wanting in cestodes and the outer layer represents a basement membrane, has been definitely set aside by the recent investigations of Blochmann; the cuticula is really the product of the subcuticular cells, though they are apparently separated from it by a considerable interval. Immediately beneath it occurs a delicate double layer of dermal muscles, having externally circular, and internally longitudinal fibres, the myoblasts of which lie deeper in the body. Between these fibres the bases of the subcuticular cells extend from the cuticula to the deeper lying bodies of the cells; the remaining space of the body between the various organs is filled with parenchymatous tissue. Within the parenchyma occur usually large numbers of calcareous bodies, highly refractive spherical or oval masses of small size, the function of which is yet uncertain. They are, however, characteristic features of cestode structure.

The cross section is divided by the parenchyme or body musculature into two regions, an external cortical layer and the median area or medullary region. In the latter are found most of the reproductive organs, although in the Bothriocephalidæ the vitellaria lie in the cortical layer. The body muscles are of three sets, longitudinal, transverse, and dorso-ventral or sagittal. The longitudinal muscles (Fig. 1204, *ml*) form the outer layer of the muscular mass broken only at the sexual pore, and though variable in amount are always numerous. The transverse muscles (*mc*), often called circular, constitute a plate just within the longitudinal fibres; at the side these fibres intersect and spread through the longitudinal muscles like the rays of a fan. The sagittal fibres extend singly or in small bundles from dorsal to ventral surfaces directly through the proglottid; they are scattered and not so numerous as the other systems of fibres.

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* Report to New York Therapeutical Society; the Medical Record, June 12th, 1880.

† A general discussion of parasitism and its effects will be found under the heading *Parasites.*

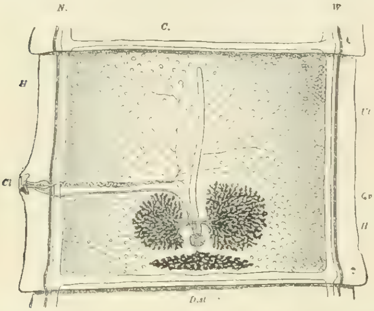

FIG. 1205.—Sexually Mature Proglottis of *Tænia saginata*. *C*, Transverse commissure of excretory canals; *Cl*, genital cloaca; *D.st.*, vitellarium; *H*, testicular follicles; *N*, lateral nerve trunk; *Ov*, ovary; *Ut*, uterus; *W*, longitudinal excretory canal. × 10.

Absolutely no trace of an alimentary tract has yet been discovered in the cestodes. Imbibition is the only known method of taking food, and the adult tapeworms are accordingly limited to those organs, alimentary canal and serous cavities, in which the parasite is bathed in a nutrient fluid.

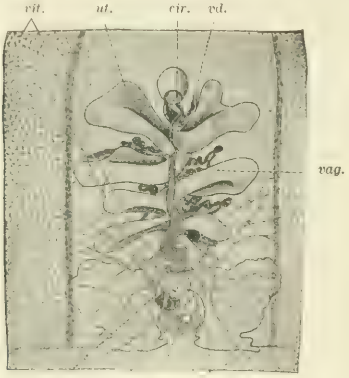

FIG. 1206.—Central Portion of the Sexually Mature Proglottis of *Dibothriocephalus latus* from the Ventral Surface. *cir.*, Cirrus sac; *ov.*, ovary; *ovd.*, oviduct; *sh.gl.*, shell gland; *ut.*, loop of uterus; *vag.*, vagina; *vd.*, coil of dorsal vas deferens; *vit.*, vitellaria; *vit.d.*, yolk duct. The numerous follicular testes lie beneath, *i.e.*, dorsal to the vitellaria shown here. (After Sommer and Landois.)

The organs of the reproductive system are grouped so that each proglottis contains a complete set, and even when the body is not segmented externally, examination of the internal structure shows them to be repeated. Each proglottis contains all the organs of both sexes (Fig. 1209) and appears in this respect a complete hermaphroditic individual. The organs first make their appearance in the anterior proglottides as indistinct cords of cells which gradually assume the character of the sexually mature condition. In general the male organs reach maturity a little in advance of the female, and copulation with an older proglottis of the same or of a different chain may hence be inferred. The male system consist of numerous small testes, the vasa efferentia of which unite near the centre of the segment to a common vas deferens, and the latter, which is commonly provided with an enlargement, the vesicula seminalis, and which terminates in a copulatory organ, the cirrus, opens with the vagina into a genital cloaca (*cl*) at the common genital pore, located either at the margin or on the surface of the segment. The female organs may be said to take their origin from the genital pore with the vagina which leads inward, furnished at some point with an enlargement, the receptaculum seminis, in which the supply of sperm is stored up. The ovary, either single or paired, empties by an oviduct which joins the vagina near the shell gland and which often has near its origin a muscular organ, the oocapt, by which the eggs are taken from the ovary and forced onward to the vagina. The vitellarium is a single, large racemose gland (*D.st.*, Fig. 1205), or a multitude of small follicles (*vit.*, Fig. 1206) in which are produced the masses of yolk material to be included in the eggs. Vitelline duct and oviduct join the continuation of the vaginal canal in the shell gland, and to this portion of the duct the name ootype has been given. Here the ovum coming from the ovary is fertilized by the spermatazoon from the seminal receptacle, is surrounded by a mass of yolk material from the vitellarium, and the whole encased in a capsule formed by the secretion of the shell gland, which rapidly hardens into a thick chitinous shell. The completed eggs are then forced onward into the uterus. Since they consist not only of a fertilized ovum but also of a mass of disintegrated yolk cells, the name compound egg has been applied to them. Such eggs occur only in the flat worms.

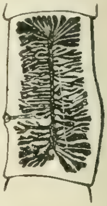

FIG. 1207.—Ripe Proglottis of *Tænia saginata* with branched uterus. × 2. (After Braun.)

The uterus may possess a special external opening or may be without such. In the latter case it is small at first, but with the accumulation of eggs it becomes irregularly enlarged by the formation of lateral outpocketings so as to occupy with its branches almost the entire space of the proglottis (Fig. 1207). In the course of this transformation other organs gradually disappear until the ripe segment is little more than a muscular sac which encloses the branching uterus crowded with eggs. The manner of branching is characteristic of the species, as is also the way in which ripe proglottides are detached either singly or in groups, and both features together with other details in the structure of the reproductive system are discussed in connection with the individual species.

The eggs of the cestodes are oval and provided with a thin shell which is often supplied with a lid. Within this occurs in many eggs (Fig. 1208) a thicker second shell, so-called, of a structure characteristic for the family in which it occurs. In reality this inner structure is not a shell but an embryonic membrane, and takes its origin during the early growth of the germ cell, which occurs in most cases while the egg is still retained in the uterus of the adult cestode. When the uterine egg is examined soon after its formation, the shell is seen to contain a single germ cell surrounded by a number of yolk cells which, in some cases, have lost their cellular identity and constitute merely a mass of granular yolk substance.

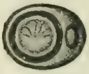

FIG. 1208.—Egg of *Tænia solium*. × 380. (After Leuckart.)

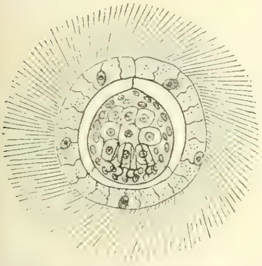

FIG. 1209.—Free Swimming Onchosphere of *Dibothriocephalus latus* in ciliated mantle. × 500. (After Schauinsland.)

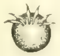

FIG. 1210. Free Onchosphere, Magnified.

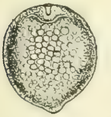

FIG. 1211.—Young Cysticercus of *Tænia saginata* with beginning of Scolex Ingrowth, Seen in Optical Section. Magnified. (After Leuckart.)

The embryo originates from the development of the egg cell alone while the yolk cells serve as nutriment during its early growth. From the division of the egg cell, which undergoes total cleavage, there arises a spherical embryo surrounded by one or more embryonic membranes. From the latter may originate an inner shell, as is the case in Tæniadæ (Fig. 1208), or a ciliated mantle, as in Bothriocephalidæ (Fig. 1209). The spherical embryo (Fig. 1210), which is known as the onchosphere, is uniformly characterized by the presence of three pairs of hooks of variable shape and by great mobility, and in this condition is ready for introduction into the secondary host. This may be the result of a direct migration, as when the ciliated bothriocephalid embryo, swimming about in the water, is swallowed by a suitable host; or it may be of passive character, as when the tænioid egg containing an embryo enveloped in its membranes arrives by chance in the alimentary canal of the larval host; in the latter case, at least, it is necessary that the eggs should be introduced into the stomach and be subjected to the action of the gastric juice to disintegrate the shell and membrane. Were this not so it is clear that the harboring of the adult in the intestine would be, in those cases in which the larva parasitizes in the same animal, a source of extensive secondary infection. In such cases it is well known, as for instance in *Tænia solium* of man, that any reversal of the ordinary peristaltic action of the canal, which brings loose proglottides into the stomach and subjects them to gastric digestion, will result in the release of the six-hooked onchospheres, and in the infection of the host with the larvæ. Once that the membranes are broken down and the onchospheres set free they bore their way actively, by virtue of the hooks, through the wall, probably in most cases of the proximal portion of the intestine, and are believed to be distributed further by virtue of the portal circulation; at least the liver and the connective tissue adjacent to it are the chief seats of the larvæ. Having come to rest at such a point the embryo throws off its hooks and forms on its surface a thick cuticular layer beneath which are differentiated the muscle fibres, while about each embryo is formed a cyst by the activity of the host. The centre of the sphere is filled at first with a loose parenchymatous tissue in which soon appear irregular spaces that later fuse to form a large central cavity. Thus has been reached the first form of the larval stage known as the bladder worm or cysticercus (Fig. 1211). A growth of two to four weeks is sufficient in most cases to bring the cysticercus to the diameter of a millimeter, when the second stage in the development is entered upon by the appearance of a meniscoid proliferation of cells at some point on the bladder; into this projection there penetrates from the exterior a hollow cylindrical ingrowth of the cuticula (Fig. 1211) forming the starting-point of the scolex of the adult worm. As the growth becomes larger the ingrowth presents the form of a flask (Fig. 1212, *A*); it is still covered throughout by a cuticular layer, and at the base of the flask there arise in reverse the structures which characterize the head of the tapeworm: at the centre the rostellum with its crown of hooks, and on the sides the suckers having, when fully developed, the characteristic form and size (Fig. 1212, *B*) of the adult.

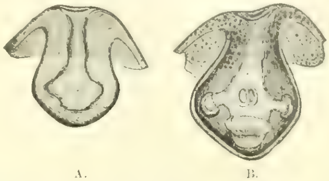

FIG. 1212.—Formation of Scolex in Reverse on Cysticercus of *Tænia serrata*. A, Early stage; B, fully developed scolex. Magnified. (After Leuckart.)

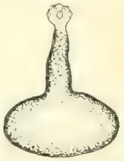

FIG. 1213. — Cysticercus of *Tænia serrata* with Everted Scolex. (After Leuckart.)

Under proper conditions the head begins to be everted, starting from the base and continuing until, with the neck, it ultimately projects above the surface of the bladder (Fig. 1213). This process may at times take place while the bladder worm is still retained within its host. In other instances the consumption of the flesh in which the cysticercus is enclosed and the digestion of the surrounding tissue form the stimulus for the evagination of the scolex. It is interesting to note that under the influence of the alimentary secretions of the definite host the bladder of the cysticercus is entirely digested, its remnant appearing as a ragged fringe (Fig. 1214, A), at the base of the fully extended scolex and neck. Having attached itself the scolex enters upon a period of rapid increase in length, which is soon accompanied by the appearance of the first proglottides (Fig. 1214, B). The scolex system of excretory canals originates early (Fig. 1208) even before the suckers and rostellum have appeared, and persist unchanged in the scolex of the fully developed adult.

In the formation of the proglottides it may be noted that the terminal proglottis is the oldest, and that new segments are continually formed in the vicinity of the neck. The sexual organs appear early as strings or masses of embryonic cells in the midst of the parenchyma. Formation of proglottides and growth proceed so rapidly that the tapeworm has matured and set free the posterior joints in a brief period. These reach the exterior with the fæcal matter, often manifesting great independence and power in movement. They contain masses of eggs stored up in the uterus with which the beginning of the life cycle is again reached.

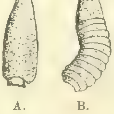

FIG. 1214. — Young *Tænia serrata*. A, Immediately after digestion of bladder by new host; B, with a few proglottides. (After Leuckart.)

The normal seat of the tapeworm is in the alimentary canal, and usually in the small intestine, where the worm lies close to the wall with its head more or less embedded in the villi. Occasionally one of the smaller species wanders from this place into the ductus choledochus, and more rarely into the liver itself. This seems to be the normal habit of a few species not found in man. The occurrence of tapeworms in the human stomach or anterior thereto, as reported by various medical observers, is due either to a postmortem wandering or to regurgitation. On the other hand the reported occurrence of Cestoda in the bladder, and the discharge of proglottides from the urethra, can be explained, in so far as the cases do not rest on erroneous observations, only on the basis of injury or accidental introduction. Portions of a tapeworm have been at times discharged from abscesses or fistulæ which have probably had at some time a connection with the intestine. Leidy's discovery of a specimen in a cucumber admits, however, of no such natural explanation. Though often torpid when examined after discharge, the tapeworm is undoubtedly, it must be remembered, active in its warm-blooded host. To its contractions are due the serious symptoms which often accompany its presence. Even the discharged proglottides live for several days outside the host under ordinary circumstances and perform migrations and movements of considerable extent. By virtue of this apparent completeness and activity, the separate proglottides are frequently diagnosed as flukes.

The effect of the parasite on its host may be regarded first from the standpoint of loss of nutriment. This has been carefully computed by Leuckart for the largest human tapeworms, and amounts in one year for a single specimen of *Dibothriocephalus latus* to from 500 to 700 gm., and for *Tænia saginata* to from 1,500 to 2,000 gm. Although the presence of a number of individuals may heighten this materially, yet the amount is entirely inadequate to explain the far-reaching effects which are manifested by man as the result of the presence of only a single one of these parasites. The severe symptoms are noticeably of a nervous character. Anæmia is a frequent manifestation, and this displays at times a pernicious tendency which in one case at least has terminated fatally.

Many of the symptoms affecting individuals who harbor tapeworms have been attributed to poisons developed by the parasite within the body of the host. Not only is this evinced by the subsidence of the nervous and epileptic symptoms on the removal of the tapeworms, but the affections of the eyes so frequent in those afflicted may naturally be due to the effects of a poison absorbed from the intestine and circulating in the blood. The fluid extracted from a hydatid cyst has been shown by experiment on man and animals to be toxic. To this quality may doubtless be attributed the severe symptoms or even death consequent upon the rupture of such a cyst or its operative puncture. An extract from *Dibothriocephalus latus* has been shown to exert a globulicidal effect on dogs, and one of *Tænia saginata* has been found to kill tubercle bacilli.

The symptoms of tapeworm disease are by no means well defined and may include almost any possible combination. In experimenting upon himself, however, Stiles noted during the presence of *Tænia saginata* as the most constant symptom one not heretofore recorded. He says: "During the time of infection it would very frequently happen as I walked along the street or across the room that I suddenly felt a peculiar sensation almost exactly similar to the sensation one feels upon the sudden descent of an elevator." Despite the indefiniteness of the clinical aspect of tapeworm infection, any suspicions of such trouble may be definitely tested by a microscopical investigation of the fæces. The presence of adult cestodes will be manifested by an abundance of their characteristic eggs.

The specifics which are most frequently employed in driving out tapeworms are Cortex granati, of which the effective principle is an alkaloid known as "pelletierine," Flores Kouso containing the amorphous kosotoxin, Rhizoma filicis containing the amorphous filicic acid, and kamala with the resinous kamalin (see *Anthelminthics*). In bringing about the evacuation of the parasite some precautions are necessary to insure success. When a patient is passing a tapeworm the parasite sometimes breaks in two owing to the transition from the warm bowels to the cold air or to a cold porcelain vessel. By the use of a vessel containing warm water this sudden change and its consequent evil effects may be avoided. In the next place cestodes are frequently expelled in a knotted mass, and any obstruction in the lower portion of the canal may delay their passage sufficiently to permit the parasite to secure a new hold on the wall. Consequently success may depend upon thoroughly clearing out the canal.

The distribution of each species will be considered under its proper heading; here, however, some general items may be noted concerning the frequence of tapeworms. Stiles gives the following table of:

CASES OF TAPEWORM IN MAN.

Authority.	Total number of cases reported.	Sex of Patients.	
		Male.	Female.
Wawruck	173	56	117
Crisp	247	96	151
Seeger	26	10	16
Monti	240*	111	129
Roger	10*	3	7
Krabbe	367	126	241
Total	1,063	402	661

* Children.

He attributes the evident sex difference merely to the fact that women ordinarily prepare the food, and are hence more exposed to chance infection than men. Statistics of French maritime hospitals give for the period 1886–90 about 1.5 per cent. of cases for tapeworm infection, and records of the United States hospital service during the war contain a total of only .012 per cent. treated for tapeworms. This percentage is under the circumstances naturally abnormally low as compared with conditions in times of peace.

The occurrence of various species in different regions may be adjudged from the following table. Such figures exist only for a very few localities:

Authority.	Country.	Dates of records.	Total number of cases.	Tænia saginata.	Tænia solium.	Diboth. latus.	Dipyl. caninum.	Hymen. diminuta.	Indet.
Parona	Milan	1899	150	121	11	4	..	..	14
Parona	Italy	1868–99	513	397	71	26	..	..	19
Krabbe	Denmark	1869	100	37	53	9	1	..	..
Krabbe	Denmark	1869–87	200	153	24	16	8	..	..
Krabbe	Denmark	1887–95	100	89	....	5	6	..	..
Stiles	U. S. A.	1897	....	Many	Rare	3	..	1	..

Cestodes have been known from the earliest times, and both tapeworms and bladder worms are distinctly recognized in the oldest medical works which have come down to us. One of the hermetic books of the Egyptians, that on medicaments now known as the Papyros Ebers, and dated about 1550 B.C., gives in hieratic writing extensive sections on these parasites and their treatment, which are taken in part from the writings of earlier physicians. The proscription placed by Moses on the use of certain flesh has its undoubted ground in the abundant presence in such animals of bladder worms. Hippocrates notes the presence of echinococcus bladders in man and an operative method for removing them. He also speaks of the evacuation of fragments like pumpkin seeds as diagnostic of the tapeworm. Both he and Aristotle speak of the bladder worm of the pig as well known, and advise the detection of its presence by examining the lower surface of the pig's tongue where the cysticerci appear as swellings. This method is followed even to-day. Aristotle showed also that the tapeworm in contrast with the free round worms of the intestine was attached to the wall of the canal. Pliny adds to the accounts of his predecessors which he quotes only fabulous reports of the length of tapeworms (up to three hundred feet!) and erroneous observations on their presence in cold springs. Galen mentions bladder worms from the abdomen of slaughtered animals and notes the tendency of the liver to "produce" these forms in its surrounding fascia.

It was 1600 A.D., however, before even two species were differentiated among human tapeworms, and 1700

A.D. before the tapeworm head was recognized. About this time cestodes from other hosts began to be studied and the animal nature of the bladder worms, which had previously been regarded as tumors or concretions, was successfully maintained. Even then authors noted the resemblance of certain cestodes and cysticerci, and in 1782 Goeze united the two groups, but this procedure was not accepted by later authors for more than half a century.

The origin of these parasites was universally attributed to spontaneous generation, the tapeworm being said to originate from the inner wall of the canal, from surplus food of a thick character like milk or cheese, or from febrile mucous secretions, while the cysticerci were generally regarded as tumors (hydatids). This belief lasted long, even after the discovery of the eggs in many species. Linnæus was responsible for propagating another serious error, that the cestodes were free living as well as parasitic; and this was not finally refuted until the end of the eighteenth century. It was Zeder who in 1800 first divided the parasitic worms into five classes to which Rudolphi in 1804 gave the Greek names, Nematoidea, Acanthocephala, Trematoda, Cestoidea, Cystica, which they still bear. Of the last two, the tapeworms and bladder worms, Küchenmeister was able to prove about the middle of the century by feeding experiments that the latter were only developmental stages of the former, thus incorporating both in the group of cestodes. Among these those forms with only a single segment may be distinguished as the Cestodaria from the Cestoda *s. str.*, in which group are included the large majority of the tapeworms, and all of the forms reported from man. The latter may be arranged according to the following scheme which adopts the system proposed by Braun. The groups omitted here contain no forms recorded as human parasites. Annotation is made of the stage in which each species is a human parasite and of those forms thus far recorded in this country:

Order Cyclophyllidea.		
Family Tæniadæ.		
Tænia saginata.	Adult in man.	U. S. A.
" africana.	" "	
" solium.	" "	U. S. A.
" confusa.	" "	U. S. A.
" serrata.	Larva in man (?)	
" marginata.	" " (?)	U. S. A.
" echinococcus.	" "	U. S. A.
Davainea madagascariensis.	Adult in man.	
Hymenolepis nana.	" "	U. S. A.
" diminuta.	" "	U. S. A. (?)
Dipylidium caninum.	" "	
Order Pseudophyllidea.		
Family Bothriocephalidæ.		
Dibothriocephalus latus.	Adult in man.	U. S. A. (?)
" cordatus.	" "	
Dibothrium Mansoni.	Larva in man.	
Diplogonoporus grandis.	Adult "	

KEY TO ADULT TAPEWORMS OF MAN.

Scolex with four circular suckers; proglottides with marginal genital pore and without uterine orifice.
Cyclophyllidea Tæniadæ. (A.)

Scolex with two longitudinal sucking grooves; proglottides with superficial genital pore and with special uterine orifice.
Pseudophyllidea Bothriocephalidæ. (B.)

(A.) Large forms; uterus in ripe proglottides with median longitudinal trunk and numerous lateral branches; eggs with thin outer and thick inner shell (embryophore). (*a.*)

(*a.*) Head unarmed with small apical fifth sucker.
Ripe proglottis 12 to 19 mm. long by 5 to 7 mm. wide; uterus with 20 to 30 slender lateral branches. *Tænia saginata.*
Ripe proglottis 7 mm. long by 12 to 15 mm. broad; uterus with 15 to 24 simple radiating branches. *Tænia africana.*

(*aa.*) Head armed with circlet of hooks.
Ripe proglottides 10 to 12 mm. long by 5 mm. wide; uterus with 7 to 10 thick branches; ovary on pore side divided by vagina. *Tænia solium.*

(*aaa.*) Head unknown.
Ripe proglottides 27 to 35 mm. long by 3.5 to 5 mm. wide; uterus with 14 to 18 heavy irregular forked branches. *Tænia confusa.*

(AA.) Small forms; eggs with thin transparent shells, in ripe proglottides grouped in capsules or irregularly distributed. (*b.*)

(*b.*) Genital pores unilateral.
Ripe proglottides broadly elliptical, 2 mm. long by 1.4 mm. wide. *Davainea madagascariensis.*
Ripe proglottides trapezoidal, 0.14 to 0.30 mm. long by 0.4 to 0.9 mm. wide. *Hymenolepis nana.*
Ripe proglottides trapezoidal, 0.75 mm. long by 2.5 mm. wide. *Hymenolepis diminuta.*

(*bb.*) Genital pores on both margins of each proglottis; genital organs also double.
Ripe proglottides elliptical. *Dipylidium caninum.*

(B.) Genital organs single in each proglottis.
Head elongated oval; length of worm 2 to 7 meters.
Ripe proglottides 2 to 4 mm. long by 10 to 12 mm. wide. *Dibothriocephalus latus.*
Head short, cordiform; length of worm hardly over 1 meter.
Ripe proglottides approximately 5 to 6 mm. square. *Dibothriocephalus cordatus.*

(BB.) Genital organs double in each proglottis.
Head not known; length about 10 meters.
Ripe proglottides 0.5 to 0.8 mm. long, 10 to 15 mm. wide. *Diplogonoporus grandis.*

In all cases reference should be made to the fuller descriptions given for each species in the text, and thus the results obtained by use of the brief criteria contained in the key controlled. Especial attention should be paid to those species which are as yet incompletely known; the writer will be glad to assist in the identification of any such.

The Cyclophyllidea possess a scolex with four circular suckers, often with an apical rostellum on which hooks are found when present. Segmentation is pronounced and the ripe proglottides do not separate until fully developed. There is no uterine aperture and the common sexual pore is located on the margin of the proglottides. The eggs are thin shelled and without a cover. The adults lie in the alimentary canal of the higher vertebrates. The order contains but a single family, the Tæniadæ.

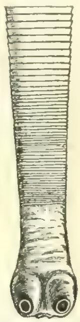

FIG. 1215.—Anterior End of *Tænia saginata*, Somewhat Contracted. × 8. (After Leuckart.)

For the genus *Taenia* the following characteristics are diagnostic. Large species with ripe proglottides much longer than broad. Uterus with median trunk and subsequently formed lateral branches during the development of which the remaining sexual organs disappear save cirrus and vagina. Larva, a cysticercus, cœnurus, or echinococcus, found in herbivorous mammals and also in man; adult in man and the carnivorous mammals.

TÆNIA SAGINATA Goeze.—T. inermis Brera, T. dentata Nicholai, T. lata Pruner, T. mediocanellata Küchenmeister, T. tropica Moq.-Tand.*

Length 4 to 8 meters or even to 74 meters (Bérenger-Féraud). Head (Fig. 1215) somewhat four-sided, 1.5 to 2 mm. in diameter, without rostellum and circle of hooks but with a sucker-like depression in its place which is often pigmented. Neck long, narrower than head. Proglottides number more than 1,000 and increase gradually in length until the ripe segments of characteristic pumpkin-seed appearance measure 16 to 20 mm. long by 4 to 7 mm. broad. Genital pores irregularly alternating, marginal, and posterior to the centre of the proglottis. Uterus in ripe proglottis with median stem and twenty to thirty-five slender lateral branches, themselves often branched. Egg shell delicate with one or two polar filaments (Fig. 1216), embryophore ovoid 35 to 40 μ by 20 to 30 μ in diameter. Adult exclusively in small intestine of man; larva (*Cysticercus bovis*) in the muscles and viscera of cattle.

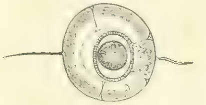

FIG. 1216.—Uterine Egg of *Tænia saginata* Showing Shell with Polar Filaments and in the Centre Onchosphere within the Embryophore. × 375. (After Leuckart.)

Structure.—The arrangement of the reproductive organs in a sexually mature proglottis (Fig. 1205) is best

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* Only the synonyms most frequently met are given under each species.

visible in a segment taken about 40 to 50 cm. from the head. The general structure of these organs has been described above. Characteristic for this species are the two ovaries of unequal size, that at the pore side being the smaller and without the small accessory lobe cut off by the vagina as in *T. solium.* The whole proglottis has a more open aspect, and the various organs show relatively greater antero-posterior diameter than in *T. solium.* The uterus in the ripe proglottis (Fig. 1207) manifests a more crowded structure, the lateral branches are slenderer and more numerous, and two or three are stunted or lacking opposite the sexual pore.

Development.—In 1861 Leuckart fed ripe proglottides of this species to calves and succeeded in obtaining the then unknown cysticercus, although various facts had pointed out cattle as the probable intermediate host. These results have been confirmed by many other investigators. At six weeks the size of the cysticercus (Fig. 1211), shelled out from its cyst, is: length 3 mm., breadth 5 mm., diameter of the head 1 mm.; at twelve weeks corresponding measurements are 4, 4, 1.8 mm. (length of head); at twenty-four weeks, 6, 4, 2 mm.; at forty-eight weeks 7, 5, 2.5 mm. The length of life of the cysticerci is brief; at less than eight months they have been found completely calcified. A temperature of 47° to 48° C. is always fatal. Of course the internal portions of roasting pieces are often far from reaching this temperature. On the other hand exposure to cold-storage conditions for three weeks is sufficient to destroy all these cysticerci contained in a piece of beef.

Artificial infection of man with the adult by eating flesh containing living specimens of *Cysticercus bovis* has been tried with equal success. An average growth of 72 mm., or about thirteen to fourteen proglottides daily, was determined.

Anomalies.—*T. saginata* appears to be peculiarly subject to variation and malformation. Excessive pigmentation of the head and chain led to the establishment of the species *T. nigra* Laboulbène (1875) for a tapeworm expelled by a Frenchman who had lived for some time in the United States. Two genital pores, on the same or opposite margins of the proglottis, but each connected with a set of reproductive organs, indicates the probable disappearance of the segmental boundaries, and this may be manifested over a considerable stretch of the worm, giving the appearance of an unsegmented body. Welch has observed such an unsegmented region 5 cm. in length. Intercalated proglottides or roughly triangular joints are not of infrequent occurrence. A common malformation consists in the perforation of a series of proglottides. This anomaly has received a specific name, *T. fenestrata*, at the hands of one observer. The fenestration appears first at the centre of the proglottis and becomes more accentuated toward the posterior end of the chain. Its cause is not understood.

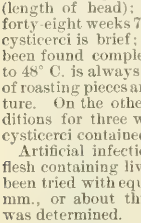

FIG. 1217. Portion of the Chain from Prismatic Specimen of *Tænia saginata*, Showing also the Occasional Separation of the Three Wings for a Short Distance. os, Sexual Pore. Natural size. (After Cattaert.)

Finally there occurs a prismatic or triradial variety (Fig. 1217) which was described by Bremser as the result of the fusion of two individuals. The proglottis is Y-shaped in cross section, and the scolex bears six acetabula. Specimens of this sort were named *T. capensis* by Küchenmeister and *T. lophosoma* by Cobbold

Onchospheres of *T. saginata* have been observed of considerable size, and armed with from twelve to twenty-two hooks; and Cobbold has described specimens of *Cysticercus bovis* from the heart of a calf with only three, two, one, and even no suckers on the head.

The form described by Weinland as *T. solium* var. *abietina*, from a specimen collected by Agassiz from a Chippewa Indian, is regarded by many as a small specimen of *T. saginata* with unusually dense and delicate branches of the uterus (Fig. 1218).

Distribution.—The adult occurs only in man and is cosmopolitan. Its presence in the Orient is recorded in writings of great antiquity; in Africa, Europe, and America it is also abundant, and its frequence has increased during recent years, whereas the contrary is true of *T. solium.* The evident reason lies in the custom of eating beef rare, but pork well done. The figures given by Bérenger-Féraud for French maritime hospitals during the six quinquennial periods from 1861 to 1890 show a steady relative increase of cases from 0.2 to 14.8 per mille. In Paris the increase, though real, was much less, being from 0.3 to 0.6 per cent. in the same time.

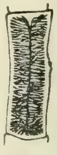
FIG. 1218.—Ripe Proglottis of *Tænia solium* (= *T. saginata* var.) var. *abietina* Weinland. (After Weinland.)

The larval form, *C. bovis*, has been produced experimentally in rare instances in other hosts, sheep and goat, but many experiments on these and other hosts have been entirely without results. In its normal host (cattle) the bladder worm was apparently rare, even in regions where *T. saginata* occurred abundantly. This apparent contradiction has been explained by the demonstration that in most cases normal infection is only mild and the cysticerci are so small and scattered as not to be easily found in the beef. Their predilection recently discovered for the pterygoid muscles affords, however, a surer means of diagnosis now than was formerly known.

A limited number of observations on the presence of *C. bovis* in man are on record. They include cases from the brain and eye, and the determination of the species rests on the absence of hooks and rostellum. Since, however, these organs may be wanting in *C. cellulosæ*, the larva of *T. solium* (*q. v.*), the determination in the cases under discussion must be viewed with suspicion.

Pathology.—Most common in hosts between twenty and forty years of age, the beef tapeworm has been encountered in the aged and even in newborn infants. Its normal place of fixation is near the pylorus, where the head is firmly fastened to the mucosa by its suckers. It may, however, be found exceptionally in the stomach. Symptoms of its presence are direct and local in the digestive system, or nervous and reflex in character. The latter are rarer but may be severe. A. Stieda has recently described a case in which this species, in spite of its lack of hooks, had bored through the wall of the duodenum and some distance in a circuitous course into the pancreas. In this case there were neither abcesses nor preformed orifices of which the worm could have made use, while other evidence supported the view of active burrowing on its part. Possibly the rare cases in which tapeworms have made their exit through the navel or bladder may be susceptible of a similar explanation. This is, however, the only case on record which has been subjected to a thorough scientific investigation.

The proglottides of this species are expelled spontaneously and in the interval between stools. The movements after expulsion are active and long continued as is evinced by the discovery of segments high on the walls of sick-room or outhouses. The anterior margin is lacerated by separation from the chain, and in crawling the proglottis distributes eggs from the uterine branches. These detached segments are frequently diagnosed as flukes, a conclusion apparently strongly confirmed by their independent activity.

This species cannot be regarded as equally dangerous with *T. solium* since here there is no chance for auto-infection by the onchospheres. The disturbances attending its presence in the alimentary canal, however, are such as to call for its removal. Despite the absence of hooks in the species this is, as a rule, more difficult of accomplishment than in the case of the pork tapeworm. The removal of the body without the head and neck constitutes but a temporary relief since a new chain is produced in a short time.

Tænia africana v. Linstow 1900.—Length 1.4 meters, greatest breadth 12 to 15 mm. Scolex unarmed, notably small, 1.4 mm. wide by 0.5 mm. long. Proglottides number about 600, decidedly broader than long; ripe proglottides measure 7 mm. long by 12 to 15 mm. broad. Uterus (Fig. 1219) with fifteen to twenty-four simple branches radiating from median trunk. Eggs thick shelled, 31 to 34 μ in diameter. Hooks of onchosphere 8 μ long. Adult parasitic in natives of German East Africa; development unknown.

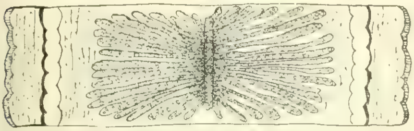

FIG. 1219. Ripe Proglottis of *Tænia africana*. × 5. (After von Linstow.)

This species, only recently described, was obtained from black soldiers near Lake Nyassa in Africa. It differs radically from the common unarmed tapeworm of man, as is evident from examination of the sexually mature proglottis (Fig. 1220). Of importance in considering its development is the report that these natives are accustomed to eat the flesh of the zebu raw.

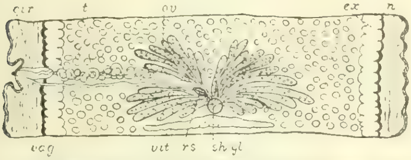

FIG. 1220.—Sexually Mature Proglottis of *Tænia africana*. *cir.*, Cirrus; *r.s.*, receptaculus seminis; *sh.gl.*, shell gland; *vag.*, vagina; *vit.*, vitellarium. × 5. (After von Linstow.)

Tænia solium L. 1767.—*T. pellucida* Goeze 1782 *T. vulgaris* Werner 1782, *T. solium* Rud. 1810. Length 2 to 3 meters, rarely 6 to 8 meters. Head (Fig. 1203) spherical 0.6–0.8 mm. in diameter. Rostrum short, often pigmented, with a double crown of twenty-four to thirty-two hooks in which large and small alternate regularly (Fig. 1221). Large hooks 0.16 to 0.18 mm. long, smaller 0.11 to 0.14 mm. long. Neck long and slender. Proglottides eight hundred to nine hundred in number, at 1 meter from the head square with sexual organs fully developed; at end of chain when ripe, 10–12 mm. long, 5–6 mm. broad. Uterus with prominent median stem and on each side seven to ten heavy branched lateral outpocketings. Embryophores 31–36 μ in diameter. Adult in small intestine of man; larva (*Cysticercus cellulosæ*) in muscles and viscera of domestic pig, rarely also of dog, man, and ape.

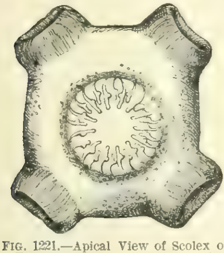

FIG. 1221.—Apical View of Scolex of *Tænia solium*. × 60. (After Leuckart.)

Structure.—In general appearance the pork tapeworm is distinctly more delicate and its chain less muscular than the beef tapeworm, previously described, and all its measurements display this difference. The scolex is decidedly smaller and has a prominent rostellum with two rows of hooks. The points of the hooks lie in a circle, but since they alternate regularly in size, the bases form two concentric circles. The hooks of the two sets show characteristic differences in figure (Fig. 1222) as well as in size.

The sexually mature proglottides do not exceed 4.5 to 5 mm. in width by 2.5 to 3 mm. in length, being thus decidedly inferior in size to those of *T. saginata*. On examination one sees the same organs in much the same relation as in the beef tapeworm; but there are minor differences which serve to distinguish the two species. Most prominent is the unequal size of the two ovaries (Fig. 1223), the one next the genital pore being the smaller and being oval in outline rather than circular. In addition a small ovarian lobe lies in the angle between the vagina and the uterus, as if cut off by the former canal from the ovary to which it apparently belongs. This accessory lobe is a constant and reliable peculiarity of the pork tapeworm. One may notice also the generally compressed form of the various organs most marked in the flattened vitellarium near the posterior edge of the proglottis.

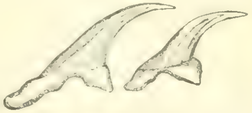

FIG. 1222.—Large and Small Hooks of *Tænia solium*. × 180. (After Leuckart.)

The differences between the two species are less evident from examination of the ripe proglottides. Usually the segments of the pork tapeworm are given off in sets of two or three rather than singly. The individual proglottis is thinner, less muscular, in general also smaller and more transparent; yet these are highly variable features and often deceptive. The form of the uterus, however, gives to the proglottis a characteristic appearance. There are only seven to ten lateral branches which are more heavily and unevenly branched, while the ends of the branches are not infrequently enlarged (Fig. 1224).

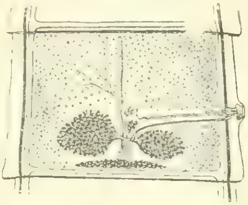

FIG. 1223.—Sexually Mature Proglottis of *Tænia solium*, Showing Reproductive Organs. × 10. (After Leuckart.)

Development.—The eggs (Fig. 1208) are oval, the outer shell is thin without polar filaments and transient; the inner shell is thick, radially striated, and spherical. The onchosphere is also spherical, measuring 20 μ in diameter. The development of the embryo is slow; in eight days it had only reached a size of 33 by 24 μ, and at the end of three weeks its diameter was but 0.8 mm., while in thirty-two days different individuals measured from 1 to 6 mm. by 0.7 to 2.5 mm. Even in the smallest, however, a head projection could be seen, and in the second month suckers and hooks are formed while the neck has grown so long as to produce one and a half complete circles within the bladder. By the close of the third month the bladder worm is probably ripe and capable of successful transference.

The longevity of the *Cysticercus cellulosæ* is dependent upon various circumstances. Not infrequently it degenerates at an early period, but more often later, by the loss of its liquid and by deposition of lime, into a mere calcareous granule. The same individual has, however, by means of the ophthalmoscope,

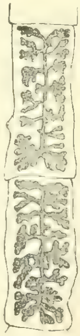

FIG. 1224.—Ripe Proglottides of *Tænia solium*, Showing Form of Uterine Branches. × 2. (After Braun.)

been observed living in the eye for twenty years. Free cysticerci live only a brief time in water, but in flesh at normal temperature they remain living up to twenty-nine days.

Many experiments have demonstrated that the *Cysticercus cellulosæ* of the pig, when introduced into the human alimentary canal, gives rise to *Tænia solium.* From ten to twelve weeks are necessary for full development and for the expulsion of the ripe proglottides. Efforts to bring the cysticercus to development in other hosts than man have as yet failed.

Anomalies.—Though less frequent than *T. saginata*, much the same malformations occur. Both incomplete and complete fusion of two or more segments and fenestration of parts of the chain are on record. An unusually slender structure of the chain gave rise to Cobbold's species, *T. tenella*, sometimes regarded as a distinct variety even yet. A scolex bearing six suckers has been observed both with an ordinary chain and with one of the prismatic or triradial variety with proglottides **Y**-shaped in cross section.

The onchosphere has at times more than the usual six hooks, and the *Cysticercus cellulosæ* is subject to various malformations. Absence of hooks, of a rostellum, and presence of six acetabula may be noted. Some abnormal forms have received special names; such a one is *C. racemosus* (*C. botyroides* or *C. multilocularis*) which is very irregular in form. This variety occurs especially at the base of the brain and is not surrounded by a cyst, to which, no doubt, is due its peculiar form, adapted to the space in which it lies. In some cases this variety is without a scolex or possesses at most but an abnormal rudiment of one.

Most interesting of all is the form which led to the establishment of a new species, *Cysticercus acanthotrias*, and by deduction a new tapeworm, *Tænia acanthotrias.* The *Cysticercus acanthotrias* was first observed by Weinland in 1858 at an autopsy of a white consumptive in Virginia. The bladder worms were in the dura mater, muscles, and subdermal tissues. Though in size and form like *C. cellulosæ*, these hydatids (Fig. 1225) possessed three rows, each of fourteen to sixteen hooks, longer and slenderer than those of that form and measuring severally 153 to 196 μ, 114 to 140 μ, and 63 to 70 μ. The discovery in several cases of identical bladder worms in European countries and the improbability of the existence there of an unknown large tapeworm with three circles of hooks, together with the occurrence in one case at least of this peculiar form side by side with *C. cellulosæ*, have led most investigators to regard *C. acanthotrias* as merely a variety of the common pork bladder worm.

Distribution.—*Tænia solium* is not so widely distributed as *T. saginata*, although partaking of the cosmopolitan character of the latter. It is rare in tropical lands, and wanting among such races as abstain from the use of pork. On the other hand, especially in those regions where the inhabitants are accustomed to eat the flesh of the pig in a poorly cooked condition, the parasite is most abundant. Certain provinces of continental nations come within these limits. Contrary to the statements of a number of standard authorities, I am confident from the evidence gathered that this species is very rare at present in the United States. Some figures have been adduced to show that it is becoming decidedly rarer in both France and Germany. In Denmark it was, in 1869, the commonest human cestode, being present in 53 out of 100 cases; in 1887–95 it was not found once in 100 cases (Krabbe).

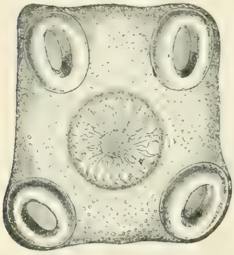
FIG. 1225.—Apical View of Scolex and Hooks of *Cysticercus acanthotrias.* × 50. (After Weinland.)

Cysticercus cellulosæ is present not only in the pig but also in the wild boar, deer, dog, cat, rat, brown bear, ape, and even man himself. In the pig the bladder worm is more abundant in such animals as are allowed to range than in those that are stall fed. In Germany the ratio of infected animals varies in different provinces from 1 in 100 to 1 in 2,000 according to reports of meat inspectors. As these cover, however, only the cases in which the infection is prominent, the actual figures are much larger. Leuckart calculated some years ago that two to three pigs per hundred were infected. This bladder worm also seems to be growing rarer during recent years.

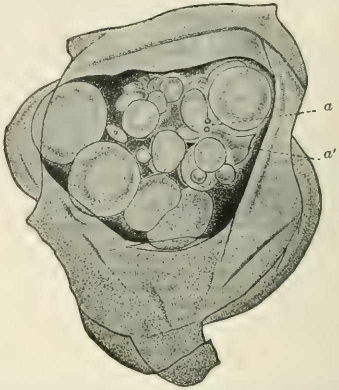

FIG. 1226.—Brain Cysticercus. Fresh specimen opened to show internal structure. *a-a'*, Stalk of racemose body (scolex). × 3. (After Kratter and Böhmig.)

Pathology.—*Tænia solium* lies with the head fastened in the anterior portion of the small intestine. The proglottides are passed in groups with fæcal matter; exceptionally through abnormal communications they reach the body cavity, bladder, and abscesses, or finally are thrown out *per os* by vomiting. The troubles caused by the worm do not differ from those due to *T. saginata*, yet the former is a much more dangerous parasite since its bladder worm may also develop in man. When abundant the bladder worms produce in pork the conditions known as "measles," and measly pork is the ordinary means of introducing *T. solium* into the human system. Rarely it may be caused by the consumption of the infected flesh of the wild pig or deer. Smoking and salting, unless extended and thorough, will not kill the bladder worms in pork and ham. Thorough cooking, however, renders them entirely harmless. As early as 1558 the cysticerci were observed in the dura mater of an epileptic. While the brain and eye are apparently the most frequent seats of the bladder worms, the latter occur also in the muscles, subdermal tissue, heart, lung, liver, peritoneum, etc. Particularly dangerous are, of course, the cerebral cysticerci (Fig. 1226) which produce effects parallel to brain tumors. In this location they are not rarely the cause of sudden death. According to Verdun and Iversenc the bladder worm of the cerebral vesicles is ordinarily free and not of the racemose variety. The acephalocystic vesicle is most common, next comes the simple form with a single head, and rarest are those consisting of a few vesicles united by the stalk. The fourth ventricle is the most frequent location of the parasite. The symptoms due to the presence of such cysticerci do not permit of certain diagnosis; most general are, however, signs of compression due to ventricular hydrocephaly.

The introduction of the onchospheres into the human stomach, which is a necessary preliminary to further development in the system, is brought about by impure drinking-water, by the use of salads or uncooked vegetables contaminated by the embryophores, and by the careless use of unsanitary closets. More frequently, no doubt, the host of the adult tapeworm infects himself through lack of cleanliness in defæcation, or possibly, as has been suggested, by internal auto-infection. Any circumstances which might lead to the passage of adult proglottides containing ripe onchospheres from the intestine back into the stomach would result in infection by those onchospheres which remained there a short time as if they had been introduced through the mouth.

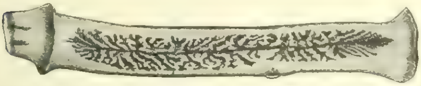

FIG. 1227.—Ripe Proglottis of *Tænia confusa.* 2.5. (Original photomicrograph.)

The danger of internal or external auto-infection demands immediate action by the physician for the removal of the parasite under great care that all regurgitation should be prevented. The success of the operation must be confirmed by the discovery of the tapeworm head, and the parasite destroyed rather than merely thrown away.

Tænia confusa Ward 1896.—This species, originally described by the writer and later studied in greater detail by one of his students (Guyer), was obtained in Lincoln, Neb. In general appearance it is much like the two species just described, but may be recognized at once by the extraordinary length of the ripe proglottides, some measuring as much as 35 mm. long by only 4 to 5 mm. broad. The shape of these proglottides differs also from that of the terminal segments in the other species (Fig. 1227, *cf.* Fig. 1207 and Fig. 1224). The head of this species is unknown, consequently its exact position and relationship are for the time being uncertain. The whole body is thinner and more fragile than that of *T. saginata.* It measures 5 to 8 meters in length and has some seven hundred to eight hundred proglottides, nearly all of which are longer than broad. The sexually mature proglottides (Fig. 1228) are distinguishable by the long reniform lobes of the ovary. In the ripe proglottides the median stem of the uterus bears fourteen to eighteen irregularly branching offshoots swollen at the end into irregular club-shaped masses. Of the approximately forty points of difference in structure between this and the common species, *T. saginata* and *T. solium*, as tabulated by Guyer, the most important are subjoined. Nothing is known of the life history of this species.

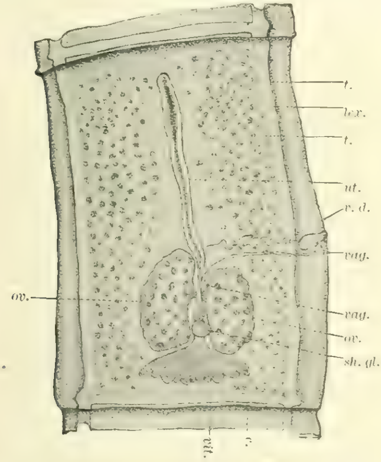

FIG. 1228. Sexually Mature Proglottis of *Tænia confusa.* × 15. (After Guyer.)

	T. saginata.	T. solium.	T. confusa.
Size of terminal proglottides.	12–19 mm. long by 5-6.5 mm. wide.	10-12 mm. long by 5 mm. wide	27-35 mm. long by 3.5-5 mm. wide.
Greatest breadth..	12-14 mm	7-8 mm	8-10 mm.
Length of proglottides exceeds breadth.	Only in last 100.	In last half....	In nearly entire worm.
Proglottides 35 cm. behind head measure.	1.5–2.6 mm. long by 5-10 mm. wide.	0.8 mm. long by 1.3 mm. wide.	1-2.5 mm. long by 0.8-3 mm. wide.
Sexually mature proglottides measure.	4-6 mm. long, 8–10 mm. wide	2.5-3 mm. long 4.5–5 mm. wide.	4–4.5 mm. long, 3.5–4.5 mm. wide.
Neck is..........	Unsegmented...	Unsegmented ..	Segmented.
Calcareous bodies.	Abundant; to 0.018 mm.	Sparse; to 0.012 mm.	Sparse; to 0.011 mm.
Longitudinal nerve trunks.	Dorsal to genital ducts.	Ibidem.........	Divide, passing both dorsal and ventral to ducts.
Depth of genital cloaca.	0.22 mm........	Smaller	0.05–0.08 mm.
Width of genital pore.	1 mm...........	Smaller	0.45–0.6 mm.
Ovarian lobes....	Round	Part of smaller cut off by vagina.	Reniform.
Lateral branches of uterus.	20-30	7-10...........	14–18
Size and form of eggs.	0.03 mm., slightly oval.	0.03 mm., nearly round.	0.039 by 0.03 mm., oval.
Pyriform process.	Present	In young proglottides.	Absent entirely.

Further information is needed regarding the frequence and distribution of this form, which though distinguishable on careful examination, has doubtless often been regarded as the common species—whence the name *confusa.*

Tænia serrata Goeze 1782.—Length 0.5 to 2 meters. Head 1.3 mm. in diameter with a double crown of thirty-four to forty-eight hooks, the larger 225 to 250 μ long, the smaller 120 to 160 μ. Embryophores oval, 36–40 μ by 31-36 μ. Adult in small intestine of dog; larva (*Cysticercus pisiformis*) in peritoneum of rabbits.

The single record of its presence in man, reported from Algeria, is undoubtedly an error in the determination of the species found. In its normal host it is common everywhere in Europe and America so far as the records stand at present.

Tænia crassicollis Rud. 1810.—Length 0.15 to 0.6 meter. Head 1.7 mm. in diameter with a double crown of twenty-six to fifty-two hooks, the larger 380–420 μ long, the smaller 250–270 μ. Embryophores spherical, 31 to 37 μ in diameter. Adult in small intestine of domestic cat and related wild species; larva (*Cysticercus fasciolaris*) in rats, mice, etc.

Braun records after Krabbe that in Jutland chopped mice are consumed uncooked on bread as a popular medicament against enuresis. Evidently the introduction of living larvæ of this species into the human alimentary canal would be not only possible but probable under these circumstances.

Tænia marginata Batsch 1786.—Length 1.5 to 5 meters. Head reniform, 1 mm. in diameter. Hooks thirty to forty-four in a double row; the larger measure 180 to 220 μ in length, the smaller 110 to 160 μ. Ripe proglottides 10 to 14 mm. by 4 to 7 mm. Uterus with short main trunk and five to eight large branches on each side. Embryophores spherical, 31 to 36 μ in diameter.

The adult lives in the small intestine of dog and wolf; larva (*Cysticercus tenuicollis*) is found in the peritoneum of apes, ruminants, and pigs. Experiment has shown that the larva will not develop to the adult worm in the human alimentary canal. The larva has been reported twice as a human parasite; but the record of its presence in the liver of man in Iceland has been shown to be a mistake. Hodges also reported its occurrence in man in the United States, but Wyman, who examined the specimens, stated that the hooks resembled rather those of *Cysticercus cellulosæ*, while the size of the cyst and the number of hooks favored *C. tenuicollis*. Since the latter features are known to be much more variable than the former, it is probable that the determination is erroneous in this case also.

Since the most dangerous of all human parasites is a dog tapeworm, and since several other canine cestodes are either known to be found or suspected to be parasitic in man at some age or in some stage of life, the dog tapeworms are evidently most important for the physician from the sanitary point of view, quite apart from the fact that by virtue of their serious effects on other domestic animals these cestodes demand attention from an economic standpoint. A strict control should be exercised over the condition of the dog in every household where such a pet is found, and the removal of the army of stray curs should be urged in every community; for these vagrants are the very ones most likely, by virtue of their omnivorous habits, to become infected and, in consequence of their nomadic life, to carry parasites from place to place. The presence of tapeworms in dogs may be recognized by the proglottides found in the fæces, and I have known of such having been taken from the back of a dog and submitted to a physician as a curiosity! Manifestation of an anal or subcaudal pruritus on the part of the dog is also good evidence of their presence. In all such cases the health of the family demands that the physician insist on the treatment of the dog for their removal.

As the determination of the species may be of importance in such cases there is appended a table, modified from Neumann, of the canine cestodes thus far reported:

Four suckers on the head.	Head armed; genital pore marginal and	Single.	Numerous proglottides. Strobila several centimeters long. Segments—	Never more than slightly broader than long. Small hooks with guard—	Bifid; hooks	230–260 μ long, genital pore very salient.	*Tænia serrata.*
						136–157 μ long, genital pore not very salient.	*T. serialis.*
					Entire; large hooks—	180–220 μ long, length of mature segments double that of their width.	*T. marginata.*
						150–170 μ long, length of mature segments treble their width.	*T. cœnurus.*
				Much broader than long except the distal segments which suddenly elongate; genital pore usually large and prominent.			*T. Krabbei.*
			Three or four segments; some millimeters long				*T. echinococcus.*
		Double and bilateral					*Dipylidium caninum.*
	Head unarmed. Sexual orifices on the ventral surface						*Mesocestoides lineatus.*
Two suckers on the head; genital pores on the ventral surface							*Dibothriocephalus fuscus.*

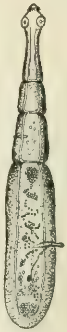

FIG. 1229.—Entire Specimen of *Tænia echinococcus* from the Dog. × 12. (After Claus.)

TÆNIA ECHINOCOCCUS von Siebold 1853.—Small cestodes (Fig. 1229) measuring from 2.5 to 5 or 6 mm. in length with only three to four proglottides the last of which measures when ripe 2 mm. in length by 0.6 mm. in breadth. Head 0.3 mm. broad with prominent rostellum bearing in a double row twenty-eight to fifty hooks which vary considerably in form and size. Onchospheres oval, 32–36 μ by 25–30 μ. Adult found in large numbers in small intestine of dog, wolf, jackal, dingo; the larva (*Echinococcus polymorphus*) in many organs of a multitude of hosts, including man.

Structure.—The adult of this species was long regarded as an immature form by virtue of its small size and limited number of proglottides until von Siebold produced it by feeding dogs with echinococcus bladders from sheep. The experiment has been repeated successfully many times with echinococcus from various sources including man, and shows a developmental period of seven to eight weeks to be necessary for the production of ripe individuals. The experimental production of the echinococcus has proved more difficult, but Leuckart has succeeded in following it by feeding the adult tapeworms to suckling pigs. The development proceeds so slowly that in one month there has been formed a spherical solid only 0.25 to 0.35 mm. in diameter enclosed in a connective-tissue cyst formed by the host, the entire mass making nodules in the liver barely 1 mm. in diameter. At two months the larvæ are twice as large, the wall consists of a thick external lamellar cuticula and a delicate granular internal membrane enclosing a watery fluid. At five months the diameter of the parasite has become 10–12 mm., but no structure is yet visible in the interior. To the parasite in this condition, consisting of cuticula, parenchyma layer (endocyst), and fluid contents, the name Acephalocystis has been applied by some authors, and frequently the organism makes no advance in structure beyond this condition. Normally, however, there appears a protuberance on the endocyst (Fig. 1230, *a*) which develops rapidly into a brood capsule (*b*) in which the parenchyma is external and the cuticular layer internal. According to the views of some investigators these may become detached and continue their development floating (*f*) in the cavity of the mother cyst, in which case, however, a cuticular layer is formed on the outside and disappears within. In the opinion of others such free daughter cysts or secondary capsules arise in the wall of the parasite when a cuticular layer is formed about small centres of detached parenchyma; as these grow they burst out from the wall, and if they fall within the mother cyst and continue their development within the cavity of the latter, the form known as an endogenous echinococcus is produced; this variety occurs most frequently in man, pig, and horse. If, on the other hand, the daughter cysts burst out from the wall of the mother cyst, their continued growth (*g*–*l*) outside gives rise to exogenous echinococci. Evidently a group of several distinct individuals may easily be confounded with a group consisting of mother and daughter cysts. Further development may also give rise to a third generation of cysts inside the second (*l*). Any or all capsules may remain sterile, *i.e.*, without heads, and such are the acephalocystic forms noted above. In most cases, however, heads are formed on the brood capsules or on the secondary cysts. According to the recent investigations of Goldschmidt a proliferation of the parenchyma layer in a brood capsule forms a low elevation (*m*). As this grows there arises inside the capsule an annular furrow, and this growing outward cuts off a pyramidal elevation (*n*) which by virtue of its early developed muscles displays great mobility, hanging outward from the brood capsule (*o*) or thrusting itself into the same as a solid linguiform structure (*p*). The external chitinous covering of the fully formed head takes its origin in a second annular furrow outside the first, which gradually surrounds the parts already described (*q*) and on its completion leaves the head projecting into the cavity of the brood capsule. Suckers and hooks originate and the entire structure presents the form of an inverted scolex (*r*). In each daughter cyst (*d*, *e*) five to ten, or even as many as thirty-four heads may develop, so that the entire number in one echinococcus reaches into the thousands. By the rupture of the brood capsule scolices may extend directly into the cavity of the hydatid or even be found floating free in its contents. The echinococcus is now mature, and if eaten by a suitable host these scolices will develop in its alimentary canal into adult tapeworms.

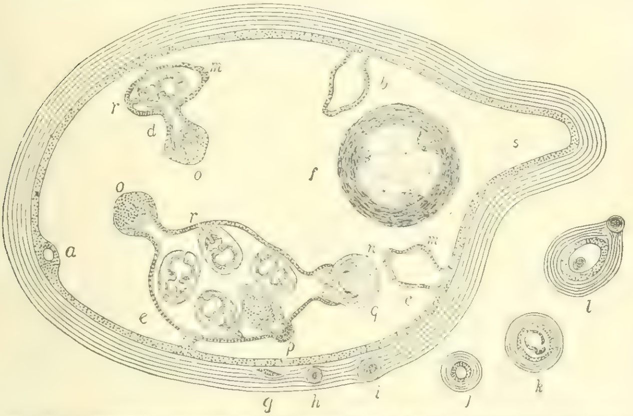

FIG. 1230. Diagrammatic Representation of Echinococcus Seen in Section. *a*, Origin of a brood capsule; *b*, *c*, *d*, further stages in its development; *e*, fully developed brood capsule; *f*, endogenous daughter cyst formed from brood capsule; *g*, origin of an exogenous daughter cyst; *h*, *i*, *j*, *k*, its further development; *l*, an exogenous daughter cyst forming an exogenous and an endogenous cyst of the third generation; *m*, origin of a scolex as a minute elevation in the wall of a brood capsule; *n*, its delimitation by a shallow internal groove; *o*, later stage; *p*, the same as last, but invaginated; *q*, the enclosing of the papilla by a second outer furrow; *r*, a fully developed scolex with head inverted. (Original.)

The form of the hydatid cyst is subject to considerable variation, the more extreme types of which have received special names. Evaginations in the wall (*s*) frequently occur under mechanical influences in the environment and suggest the origin of the form known as *E. racemosus* (Fig. 1231), from which, however, *E. multilocularis* cannot be distinctly separated in all cases. The latter, known also as an alveolar colloid, represents a mass of many small hydatids 0.1 to 5 mm. in diameter which in section display numerous irregular cavities filled with a transparent gelatinous substance and embedded in a common stroma of connective tissue. Gall duct and blood-vessels may be detected in places, but the liver cells are completely atrophied. These growths were long interpreted as colloid cancers until Virchow demonstrated their hydatid origin. The scolices or hooks, often rare and single or at most few in any bladder, are entirely wanting in forty per cent. of the specimens tested. These multilocular hydatids undergo regularly degenerative processes by which a central cavity is formed filled with a fluid containing among tissue remnants also calcareous corpuscles, secondary bladders, brood capsules, scolices, hooks, hæmatoidin and margarin crystals, concretions, etc. The size of the hooks (Fig. 1232), which varies very considerably, is due, as Leuckart has shown, to the age and stage of development of the specimen.

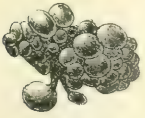

FIG. 1231.—*Echinococcus racemosus*. Natural size. (After Leuckart.)

Anomalies.—A specimen of *T. echinococcus* has been described with six suckers on the head. Regarding the larval form some observers hold that the varieties noted above as *Acephalocystis*, *E. racemosus* and *E. multilocularis* are abnormal. According to others the latter form, which appears to be confined to Switzerland, represents a different species from the common type. Isolated cases have, however, been reported from other localities, one even from the United States (Stiles).

Distribution. — The adult parasite appears to be most common in Iceland, where it occurred in 28 per cent. of the dogs examined. In Australia the percentage is even higher, 40 to 50 per cent. being recorded. On the continent of Europe it occurs in from 0.4 to 7 per cent. of the dogs examined in different localities. Stiles records its presence, though very rarely, in dogs examined at Washington, D. C. I have found no other record of the presence of the adult tapeworm in this country. When present its occurrence in large numbers is natural. The hydatid is most abundant in Iceland and in India, where from one-fourth to three-fourths of all domestic animals are infected. In Germany, where records are of a most precise nature, the percentage of infection varies very greatly, being as low as 5 per cent. in a few cases and as high as 65 per cent. in one locality (for precise figures see Stiles and Hassall, p. 122). In the United States hydatids have been recorded from cattle, hog, and camel, and for localities in Maryland, the District of Columbia, Missouri, Nebraska, and Louisiana. In New Orleans 117 cases of liver echinococcus were recorded from 2,000 hogs.

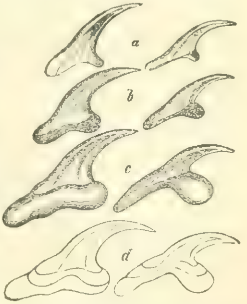

FIG. 1232.—Echinococcus Hooks. *a*, From bladder worm of cow; *b*, from young *Tænia echinococcus*; *c*, from adult *Tænia echinococcus*; *d*, the three forms superposed to show gradual modification in form. × 500. (After Leuckart.)

In man the frequency of hydatid disease corresponds in general with that for domestic animals. In Iceland estimates of the number of inhabitants infected vary from 2 to 15 per cent.; in Australia 3,000 cases were reported between the years 1861 and 1882. In Europe the results of autopsies are given in the table at the top of the next page, which is taken from Ostertag.

In this country the hydatid is rare in man. Sommer has compiled statistics of one hundred recorded cases

Locality.	Total number of autopsies.	HYDATIDS PRESENT.	
		Cases.	Percentage.
Rostock	1,025	25	2.43
Breslau	1,360	20	1.47
Berlin	4,470	33	.76
Göttingen	639	3	.46
Dresden	2,002	7	.34
Vienna	1,229	3	.24
Prague	1,287	3	.23
Erlangen	1,812	2	.11

from which the following data are taken. It is entirely unknown how many patients were infected outside the limits of this continent; certainly some of them acquired the parasite in other countries.

BY SEX.

Males	47	Unstated	25
Females	28		

BY NATIVITY.

Azorian	1	Mulatto	2
Colored	1	Negro	2
English	5	Pole	1
Foreigners	2	Swede	1
French	2	Welsh	1
German	15	White	4
Irish	2	Unstated	54
Italian	5		
Japanese	1	Total	100
Mexican	1		

BY STATES.

Alabama	2	New York	33
California	1	Ohio	7
Connecticut	1	Pennsylvania	10
District of Columbia	4	Tennessee	1
Illinois	3	Texas	1 (+ ?)
Indiana	1	Vermont	1
Kentucky	2	Virginia	2
Louisiana	1 (or 2?)	Washington	1
Massachusetts	5 (or 6?)	Unstated	15
Michigan	1		
Missouri	7	Total	100
New Jersey	1		

Caution should be exercised in the identification of supposed echinococcus bladders from domestic animals since the hydatid of *Tænia serialis* of the dog, which is abundant in the United States, is large, at times even of very considerable size, and produces numerous secondary bladders both internally and externally, so that the general appearance suggests that of echinococcus. The size and form of the scolices and of the hooks are so very different that even a superficial microscopic examination serves to distinguish the two forms. The hydatid of *Tænia serialis* is common in the rabbit and has also been reported from the horse.

Pathology.—The larva gives rise to the hydatid or echinococcus disease, the symptoms of which vary with the seat of the parasite. Cases are on record in which the hydatid has existed for 2, 4, 8, 15, 18, and even 30 years in man. It may be found in any organ, but is most frequently recorded from the liver or lungs. At times its presence is not suspected until revealed by post-mortem examination; and the danger depends in any case upon the precise location and the size attained by the hydatid. In some situations hydatids exert a fatal pressure upon important vessels or nerves or destroy the tissue of essential organs. They often cause fatal results by bursting into a serous cavity or a blood-vessel, the toxic effect of the fluid having been noted already. Somer gives the following table for 1,806 cases recorded in various countries:

CLASSIFICATION BY HABITAT.

	United States.	Canada.	Other countries.	Total.
Liver	62	7	942	1,011
Lung	7	..	140	147
Passed *per rectum*	2	..	....	2
Spleen	3	2	37	42
Brain	3	..	....	3
Abdominal wall	1	..	....	1
Vomited	2	..	....	2
Expectorated	2	..	....	2
Common bile duct	2	..	....	2
Bones	1	..	....	1
Bladder	6	..	....	6
Eye	1	..	....	1
Pericardium	1	..	....	1
Ovaries	1	..	....	1
Uterus	3	..	....	3
Trunk and limbs	..	..	4	4
Kidneys	3	..	123	126
Neck (fascia)	1	..	....	1
Stomach	1	1	....	2
Extensors of thigh	1	..	....	1
Pleura	1	..	19	20
Circulatory apparatus	..	..	53	53
Cranial cavity	..	..	91	91
Spinal canal	..	..	13	13
Pelvis	3	2	70	75
Peritoneum and omentum	1	..	61	62
Mesentery and omentum	1	..	....	1
Female genital organs and mammaries	..	..	60	60
Male genital organs	..	..	9	9
Face, orbit, and mouth	..	..	41	41
Neck	..	..	18	18
Abdomen	2	..	....	2
Omentum	1	..	....	1
Brain (ventricles)	1	..	....	1
Totals	113	12	1,681	1,806

Prevention.—As "hydatid disease is the most fatal zooparasite disease which affects man, fifty per cent. of the cases dying within five years after infection," too great insistence cannot be laid upon the necessity of guarding against the disease and stamping it out. Measures should be taken to destroy all stray dogs, to prohibit the presence of dogs at abattoirs, to destroy all hydatids found in slaughtered animals, and to discourage all intimate association with dogs. Methods for the treatment of echinococcus diseases in man have been suggested, but surgical interference alone has met with satisfactory results.

DAVAINEA R. Blanchard 1891.—Small cestodes with prominent rostellum, sometimes retractile, armed with many small hooks of characteristic form, which may be caducous. Genital pores unilateral, or alternating irregularly. Eggs in capsules. Development unknown.

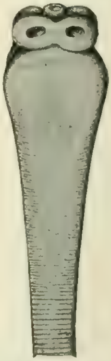

FIG. 1233.—Anterior End of *Davainea madagascariensis.* × 14. (After Blanchard.)

DAVAINEA MADAGASCARIENSIS R. Blanchard 1891; *Tænia demerariensis* C. W. Daniels 1895.—Length up to 24 cm. with five hundred to six hundred proglottides. Head (Fig. 1233) with retractile rostellum having ninety hooks, 18 μ in length, which may be wanting. Genital pores unilateral. Ripe proglottides 2 mm. long, 1.4 mm. broad. Eggs in groups surrounded by heavy capsules of parenchyma forming the characteristic egg balls which fill the entire ripe proglottides. Onchospheres 8 μ in diameter with six delicate nearly straight hooks, surrounded by two transparent membranes of which the outer has two pointed prolongations.

The growth of the cestode is very rapid. At 3 cm. from the head proglottides may be seen in copula. The last hundred segments, which make up more than half of the entire length of the worm, contain only eggs about which the capsules are forming. The characteristic appearance of the ripe proglottis is given in the figure (Fig. 1234). Of the development nothing is known. Blanchard surmises that the larval host is a cosmopolitan insect (*e.g.*, cockroach), which tallies well with known facts regarding the parasite.

Ten cases of the occurrence of this cestode in man are on record; they are distributed over the tropics, including both hemispheres. With one exception all individuals affected were infants or children. Although not yet recorded from any other host, it should be noted that the species may be only an adventitious parasite of man.

HYMENOLEPIS Weinland 1858; *Diplacanthus* Weinland.—Scolex small, rostellum retractile, armed; suckers unarmed. Genital pores on left margin; three testes in each proglottis. Ripe uterus fills entire proglottis. Eggs spherical or elongated with three widely separated membranes. Larval stage a cercocystis or staphylocystis.

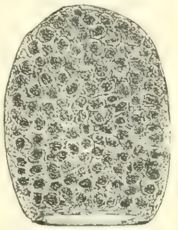
FIG. 1234.—Ripe Proglottis of *Davainea madagascariensis* just Liberated from the Chain. × 10. (After Davaine.)

HYMENOLEPIS NANA R. Blanchard 1891; *T. ægyptiaca* Bilharz, *Diplacanthus nanus* Weinland.—Length (Fig. 1235) 10 to 15 mm. rarely 20 mm., breadth 0.5 to 0.7 mm. Spherical scolex (Fig. 1236) 0.25 to 0.3 mm. in diameter with retractile rostellum armed with a single circle of twenty-four to thirty hooks which are only 14 to 18 μ long. Neck long, proglottides about one hundred and fifty in number, very short, the largest measuring only 0.4 to 0.9 mm. wide by 0.14 to 0.3 mm. long. External egg membrane measures 30 to 40 rarely 50 μ, in diameter, the onchosphere membrane 16 to 20 μ. Adult in the small intestine of man.

The development of this species is still unknown. Grassi regards it as identical with *H. murina* from the rat. According to his investigations this latter form develops directly without any secondary host, so that the chance consumption of ripe proglottides or of onchospheres would ultimately produce the adult tapeworm. Other authors have emphasized a series of differences in detail which militate against the identity of the two forms. In experiments with six persons who had swallowed ripe proglottides of *H. murina*, Grassi obtained specimens of *H. nana* only once, which in a region where the latter is abundant proves nothing. On the other hand the same investigator was unable to infect rats by feeding them ripe proglottides of *H. nana*. The evidently close relationship of the two species is presumption in favor of a similar mode of development.

Discovered in 1851 by Bilharz in Egypt it has been reported occasionally from Russia, Germany, England, France, Argentine, and the United States. In Italy it appears to be comparatively abundant. The single record of its occurrence in the United States (Spooner, 1873) is somewhat uncertain since the author mentions the possibility that the form described belonged to the following species.

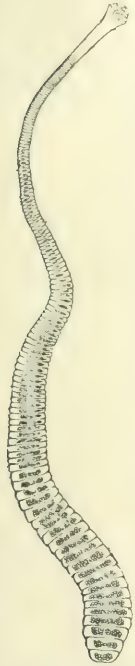
FIG. 1235.—Entire Specimen of *Hymenolepis nana*. × 15. (After Leuckart.)

Hymenolepis nana has been found chiefly in infants, less commonly in children, and only very rarely in adults. It occurs in considerable numbers, two hundred and fifty to one thousand and over, and gives rise to more serious disturbances than are attributable to the large cestodes. In addition to gastric disturbances, secondary reflex nervous symptoms, even epilepsy, have been observed; though of long standing they disappear with the removal of the parasites.

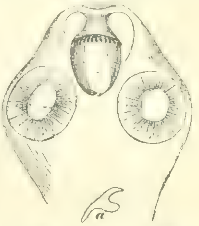

FIG. 1236.—Scolex of *Hymenolepis nana* with Rostellum Retracted. × 80. *a*, Isolated hook. × 480. (After Leuckart.)

HYMENOLEPIS DIMINUTA R. Blanchard 1891; *T. diminuta* Rud., *T. leptocephala* Creplin, *T. flavopunctata* Weinland, *T. varesina* Parona, *T. minima* Grassi.—Length 20 to 60 cm., width 3.5 mm. Head (Fig. 1237) small, claviform, with rudimentary unarmed rostellum. Neck short. Proglottides short and indistinct at first, increasing gradually to a maximum near the posterior end of the chain of 0.66 mm. long by 3.5 mm. wide. External egg membrane, 60 to 86 μ in length, internal with polar projections; onchospheres, 36 by 28 μ. Adults in small intestine of various rats and mice, and rarely also of man; larvæ (cerocystis) in various insects, chiefly the meal worm (*Asopia farinalis*).

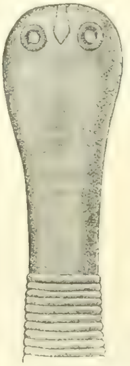
FIG. 1237.—Anterior End of *Hymenolepis diminuta*. Magnified. (After Zschokke.)

The structure of the species is typical for the group. It has been studied with great care by Zschokke. The arrangement of organs in the sexually mature proglottides is evident from the figure given (Fig. 1238). In the ripe proglottis the egg-filled uterus occupies the entire space within the walls of the segment save for the large flask-shaped cirrus. Sterile proglottides of smaller size and without eggs occur at times in the series.

The larval form, a cerocystis, occurs in many insects, Lepidoptera, Coleoptera, and Orthoptera. Its usual host is the larva and adult of a small moth (*Asopia*). The development to the adult form has been observed in white rats and in man where some fifteen days intervene before the appearance of ripe eggs in the fæces.

This species was first collected from man in Boston in 1842, and described by Weinland in 1858, who regarded it as a new species, *T. flavopunctata*. In 1884 Leidy recorded it from Philadelphia. It has also been observed as a human parasite in Italy and France, and may be met with more widely since its normal host, the rat, is a cosmopolite.

Heretofore it has been found only in infants and children, and the introduction of the larval parasite was probably due to eating fruit or other food in which an infected insect or grub was concealed.

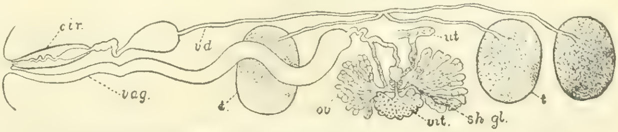

FIG. 1238.—Reproductive Organs of *Hymenolepis diminuta*. (Letters as before.) Magnified. (After Zschokke.)

Dipylidium R. Leuckart 1863.—Rostellum retractible, armed with several annular rows of alternating hooks. Genital pores opposite, organs doubled. Uterus at first a reticulum, which later becomes changed into sacs holding one or more eggs each. Eggs with double shell.

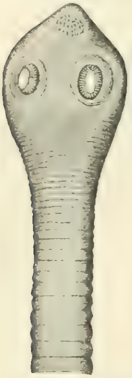
Fig. 1239.—Anterior End of *Dipylidium caninum*. (Original.)

Dipylidium caninum Railliet 1893; *T. moniliformis* Pallas, *T. cucumerina* Bloch, *T. elliptica* Batsch.—Length 10 to 40 cm., greatest width 1.5 to 3 mm. Scolex (Fig. 1239) small with retractile claviform rostellum armed with three or four rows of thorn-shaped hooks which decrease in size from 15 μ in the first row to 6 μ in the last; suckers elliptical, neck short. First proglottides small, becoming trapezoidal and finally characteristically of melon-seed form. Eggs spherical, 43–50 μ in diameter; onchosphere, 32 to 36 μ in diameter. Adult parasitic in the small intestine of the dog, cat, and rarely also man; larva (cryptocystis) in the body cavity of the dog flea and dog louse.

The most striking feature of the structure of this species is the doubling of the reproductive organs, a complete set with genital pores and copulatory organs being present on each side of the proglottis (Fig. 1240). The branches of the uterus, however, become cut off as small capsules containing eight to twelve eggs each; in the ripe proglottis the mass of such capsules fills the entire middle field, and a reddish-brown substance deposited around the eggs imparts a characteristic pink color to these segments. Prismatic and fenestrated specimens have been observed, and also individuals in which four sets of organs lay in a single proglottis.

The onchosphere is transformed in the body cavity of the dog flea, or even of the human flea, into a tailed larva, or cryptocystis. When the dogs, annoyed by the work of the fleas, hunt out and destroy these pests, it is easy to see how they infect themselves.

With a single exception all recorded cases of this tapeworm in man are among children who have by some chance obtained the larva of the parasite from playing with dogs. The first case on record dates from Linnæus, and other cases have been reported from England, Germany, France, Russia, and Scandinavia. Judging from the frequence of the parasite in dogs in this country, similar cases should not be rare here. I have found none definitely recorded.

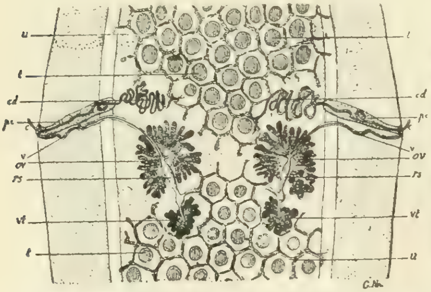

Fig. 1240.—Median Portion of Sexually Mature Proglottis of *Dipylidium caninum*; *c*, cirrus; *ov*, ovary; *rs*, seminal receptacle; *t*, testis; *u*, uterus; *v*, vagina; *vt*, vitellarium. × 25. (From Railliet, after Neumann.)

The order Pseudophyllidea is characterized by the presence on the scolex of two poorly developed sucking grooves which may be in some cases much modified. Of the three sexual pores the uterine orifice lies always on one surface of the proglottis, whereas the two others may be on the same or opposite surface, or on the margin of the proglottis. The sexual organs are generally single, rarely doubled; their development does not transcend the stage of maturity so that no parts degenerate. Eggs usually with cover. Among the twenty-one genera known, only two are of immediate importance here.

Dibothriocephalus Lühe.—Scolex elongated; suckers not powerfully developed; genital organs single; genital pores ventral; uterus in coils in centre of the proglottis producing a characteristic rosette figure (Fig. 1241).

Dibothriocephalus latus Lühe 1899; *Tænia lata* and *T. vulgaris* L. 1748; *Bothriocephalus latus* Bremser 1819; *Dibothrium latum* Dies 1850. Length, 2–9 meters, rarely up to 20 meters, grayish yellow; head elongated oval, 2–3 mm. long, 0.7–1 mm. broad, transversed by two deep lateral grooves. Proglottides, three thousand to four thousand in number, usually broader than long but becoming gradually quadratic. All sexual pores on mid-ventral line, cirrus and vagina opening close together and in front of uterus. Eggs, 68–70 μ by 45 μ. Adult parasitic in small intestine of man, dog, and cat; larva (plerocercoid) in the muscles and among the viscera of various fish.

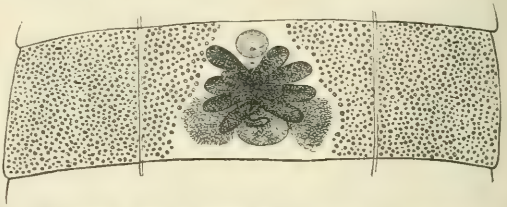
Fig. 1241.—Ventral Aspect of Sexually Mature Proglottis of *Dibothriocephalus latus*, Showing Female Reproductive Organs. (*Cf.* Fig. 1206.) × 12. (After Leuckart.)

Structure.—The longitudinal sucking grooves, characteristic of these forms, occupy in reality the upper and lower face of the head, appearing at the sides in consequence of the torsion of the neck. In external appearance the chain is clearly distinguishable from the other large human tapeworms, *T. saginata* and *T. solium*, by its greater thickness at the middle of the segment. The arrangement of the sexual organs in the proglottis (Fig. 1206) also differs radically from that already described in the genus *Tænia*. The numerous testes occupy a lateral position in the medullary region of the segment, and the vas deferens extends in loops toward the anterior end, terminating in a muscular cirrus pouch with a seminal vesicle. Next the male genital pore lies the orifice of the vagina which passes directly posteriad in the median line, and after forming a receptaculum seminis joins the common yolk duct near the centre of the voluminous shell gland. The vitellaria or yolk glands are racemose structures occupying the cortical layer of the segment in the lateral fields; their numerous ducts converge and ultimately unite into the common yolk duct noted above. The paired ovaries lie one on either side of the shell gland in the posterior region of the proglottis, and the oviduct joins the vagina and the yolk duct in the shell gland. From the union of these ducts originates a canal which expands, and as the uterus, lying in irregular loops ventral to the vas deferens, extends forward to the special uterine orifice, a simple pore in the mid-ventral line a short distance behind the common opening of the cirrus and vagina. In the last proglottides the uterus is often empty of eggs and the genital glands are atrophied.

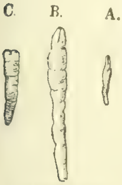

FIG. 1242.—Plerocercoids of *Dibothriocephalus latus* from Pike. *A*, Natural size; *B*, *C*, with scolex protruded and retracted. ×2. (After Leuckart.)

Development.—Ripe proglottides contain numbers of brownish, elliptical eggs in which may be distinguished the egg cell surrounded by masses of yolk cells. After lying in water several weeks a ciliated onchosphere (Fig. 1209) is hatched out and swims about in the surrounding water. Sometimes this embryo throws off the ciliary covering, but ultimately dies without attaining any further development. How the onchosphere is transformed into a plerocercoid remains still undiscovered. Braun was inclined to believe in the necessity of another intermediate host, and Leuckart and others have endeavored in vain to infect directly with onchospheres the various fish which harbor the larval form. The bladder worm of *Dibothriocephalus latus* was first discovered by Braun in the muscles and viscera of food fish in the Baltic provinces. It is an elongated form known as a plerocercoid (Fig. 1242), and measures 8–30 mm. in length. These larvæ were abundant in fresh fish from Dorpat markets, and living specimens were also obtained from smoked, salted, and frozen fish as well as in the roes of the pike, which salted are eaten raw as caviar. Experimentation on dogs, cats, and man established the connection of this larva with the adult *Dibothriocephalus latus.* Other authors, notably Zschokke in Switzerland (Geneva), have discovered the larvæ in perch, salmon, trout, grayling, and whitefish, and in some instances have determined experimentally their relation to the species of cestode under consideration, confirming fully the discoveries of Braun. In Scandinavia, Lombardy, Switzerland, and Japan the existence of the plerocercoid in various fishes and the consumption of some part of the latter in a raw condition by the native population explain the method of human infection which has been further determined experimentally in specific cases.

Once introduced into the human alimentary canal the development of this tapeworm is very rapid, being from 5 to 9 cm. per day in the various cases. Eggs appear in the fæces of man in from twenty-four to thirty days after infection.

Anomalies.—Slender specimens (var. *tenella*) have been recorded, as also some with exceptionally large proglottides. One specimen of the prismatic variety is on record (*cf. T. saginata*) and fenestration of greater or less extent is not rare. Most frequent, however, is the reduplication of the genital pores and organs which Leuckart says he has never failed to find in some proglottis of each specimen examined. Under a separate name (*Bothriocephalus cristatus*) Davaine described a variety which is distinguished from the common by possessing a projecting longitudinal ridge on each flat surface of the head.

Geographical Distribution.—The peculiarities in the distribution of this species are intelligible in the light of its development. It is abundant on the shores of the Baltic, especially the Russian and east Prussian, and around the lakes of French Switzerland, while the territory adjacent to these regions furnishes sporadic cases varying greatly in frequence. Small centres, like Munich (Bavaria), are known to exist, where the origin of the parasite has been attributed to the fish of a certain lake or lake region. In Africa a new centre has been reported recently in the territory around Lake N'gami. In Japan this form is the most abundant of human and canine parasites. Its presence in other regions than those noted has been recorded occasionally, and usually in persons known to have come from the infected regions. Of this type is the record of its presence in Philadelphia made by Leidy. According to Zschokke this species is becoming rarer in Geneva, its frequency having fallen in thirty years from ten to one per cent., and in Paris where it was abundant in the eighteenth century it is no longer autochthonous.

Pathology.—It is sometimes solitary, though several individuals occur together in the majority of cases and nearly one hundred have been recorded from a single host. Evidently its frequence depends upon the habits of the individual in eating raw or poorly cooked fish no less than upon the locality. The effect of the parasite is often unnoticed; in other cases are noted gastric and nervous disturbances, and even pernicious anæmia, which disappear with the removal of the worm. These troubles have been attributed to the production of some toxic substance by the parasite. It should be noted that a self-infection is impossible.

DIBOTHRIOCEPHALUS CORDATUS (Leuckart 1862).—Length, 80 to 115 cm. Head (Fig. 1243), 2 mm. in diameter, flattened cordiform, with deep bothridia on ventral and dorsal surfaces. Segmentation begins directly behind the head; the proglottides, which increase rapidly in width, become mature within 3 cm. The largest proglottides measure 7–8 mm. in length by 3–4 mm. in breadth and number about six hundred. Eggs, with cover, measure 75 μ by 50 μ. Adult parasitic in seal, walrus, dog, and man in Greenland; larva unknown.

The adult is a common parasite in its native land, but records of its presence outside of Greenland are based on errors. However, sporadic cases may occur in those who have become infected while visiting its native home. The intermediate host is doubtless a fish.

DIBOTHRIUM MANSONI Ariola 1900. *Ligula Mansoni* Cobbold; *Bothriocephalus liguloides* Leuckart.; *B. Mansoni* R. Bl.—Adult unknown. Larva a plerocercoid; length, 12 to 20 or even to 35 cm.; breadth, 3–6–12 mm.; flattened without proglottides, but marked by irregular folds. Anterior end enlarged, bearing the head which may be drawn in or evaginated, and on which two faint bothridia are visible. Parasitic in connective tissue of man in Japan and China.

Ten cases of the occurrence of this parasite are reported, one from China and the rest from Japan. It was first found by Manson in an autopsy when a dozen specimens were taken from below the peritoneum, and one free in the peritoneal cavity. Ijima and Murata have described in detail seven cases from Japan; in three the parasite was passed with urine or taken from the urethra, in three cases also it was drawn from tumors of the eye, and in one from a cavity in the subcutaneous connective tissue of the thigh.

Doubtless the larva wanders about in the body of its host, in which, as appears from the details of the last case cited, it may remain active as long as nine years. Ultimately it reaches the surface of the body or of an internal organ (bladder) from which it eventually attains the exterior. Of its origin or its further development nothing is known. No trace of reproductive organs could be found in the specimens studied. In its unusual size and in the presence of longitudinal grooves on the ventral surface, this larva resembles the following species of which the adult alone is known.

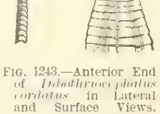

FIG. 1243.—Anterior End of *Dibothriocephalus cordatus* in Lateral and Surface Views. × 5. (After Leuckart.)

DIPLOGONOPORUS Lönnberg 1892, *Krabbea* R. Blanchard 1894.—Genital organs doubled in each proglottis; in other respects identical with those of *Dibothriocephalus.* Genital orifices of each set ventral on either side of the median line of the body, but in the median line of either uterine field.

DIPLOGONOPORUS GRANDIS Lühe 1899; *Krabbea grandis* R. Blanchard.—Length, 10 meters or more; maximum breadth at anterior end 1.5 mm., in broadest region 25 mm. Proglottides very short, near posterior end only 0.45 mm. in length by 14 to 16 mm. in breadth. Scolex unknown. Genital organs double; two lateral rows of sexual openings on the ventral surface, located in longitudinal grooves with genital sinus in front and orifice of uterus behind it. Eggs brown, thick shelled, 63 μ by 48 to 50 μ in diameter. Found in man in Japan; larva unknown. The first account of this remarkable species was given by Ijima and Kurimoto. It is unique not only in the extreme size manifested, but also in the double genital apparatus which occurs in some species from seals, but save for this species is unknown among human parasites of this group. The sexual organs (Fig. 1244) are characteristically bothriocephaline, but they are found in double sets right and left in each segment, and the orifices open at the bottom of two longitudinal grooves which are characteristic features in the appearance of the worm (Fig. 1245).

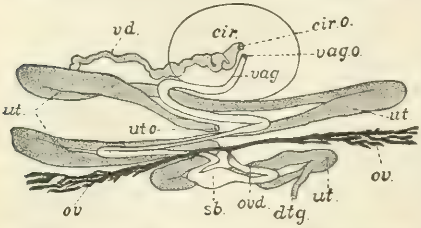

FIG. 1244.—Sinistral Set of Reproductive Organs from Sexually Mature Proglottis of *Diplogonoporus grandis.* × 140. (After Ijima and Kurimoto.)

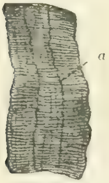

FIG. 1245.—Ventral View of Portion of Chain from *Diplogonoporus grandis.* *a*, Ventral groove. Natural size. (After Ijima and Kurimoto.)

The authors report that the patient had suffered for five years from dizziness and colic which had finally become so severe as to call for his admission to the hospital at Nagasaki. Here the parasite was removed and even on the following day all the trouble of long standing had entirely disappeared. In view of our rapidly growing intercourse with the East this should be looked for among the unwelcome additions which are sure to be made to our helminthological fauna.

Quite recently Kurimoto has given an account of a second case (also from Japan) in which two specimens of the same parasite were passed. Unfortunately, both scolices were wanting here also. In other particulars the agreement with the original specimen of this species was complete. Anomalies such as fenestration, intercalated proglottides, and those of asymmetrical form were frequent. *Henry B. Ward.*

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CHALYBEATE SPRINGS. — Meriweather County, Georgia.

POST-OFFICE.—Chalybeate Springs. Hotels and cottages.

ACCESS.—Take Southeastern Railroad to Bostwick, thence Talbottom Branch Road to Talbottom, thence 20 miles west to Springs.

These springs were discovered by Mr. Rawlings about 1835, and opened by him for the reception of visitors a few years later. The improvements were of a rude character until about 1850, at which time they were considerably enlarged. With the exception of a few years' interval they have been open to the public ever since. Analysis by Prof. W. J. Land:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Silicic acid (soluble)	2.83
Iron proto-carbonate	.62
Iron sesqui-carbonate	.17
Lime carbonate	.76
Potassium sulphate	.33
Sodium sulphate	.13
Aluminum sulphate	.43
Sodium chloride	.03
Total	5.30

Carbonic acid gas, 6.55 cubic inches.

The water is a light chalybeate. There are also traces of hydrogen sulphide, carbonate of magnesia, crenate of iron, and a minute trace of nitric acid, lithium, and organic matter. The proportion of soluble salicylic acid is larger than usual. This compound is not used in medicine, but silica is contained in the human body, and may not be without therapeutical value. It is possible that the trace of sulphureted hydrogen also slightly influences the action of the water. It has been recommended in all cases requiring a chalybeate water. The flow is abundant, being about twenty-five gallons per minute. Near by is a sulphur and magnesia spring, but no analysis has been made of the waters. The improvements are extensive, consisting of two hotels and cottages, sufficient to accommodate five hundred guests. Bathing facilities are ample, both hot and cold water being supplied. The climate of this region is of a salubrious character.

James K. Crook.

CHAMÆLIRIUM. See *Unicorn Root, False.*

CHAMIQUEL.—Coalcoman, Michoacan, Mexico. A lukewarm mineral water classified by Dr. Zuniger as a sulphureted calcic water, and containing, according to Forbes, of Coalcoman, carbonic acid, large quantities of lime and magnesia, silica, and traces of copper and iron.

No bathing facilities have been established so far. The bathers are recruited from among those suffering from leprosy and diseases of the skin. *N. J. Ponce de Léon.*

CHAMOMILE.—*ANTHEMIS* *Roman Chamomile.* "The flower heads of *Anthemis nobilis* L. (fam *Compositæ*), collected from cultivated plants" (U. S. P.). In this definition the Pharmacopœia recognizes the fact that under cultivation the aroma and flavor of the chamomile grow finer and less rank and heavy, notwithstanding that the percentage of volatile oil, and very likely the medicinal strength, are somewhat decreased.

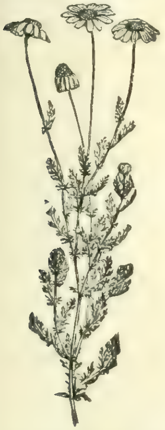

FIG. 1246. Chamomile, Wild or Single-Flowered Plant. One-third natural size. (Baillon.)

The chamomile plant is a native of Europe and is largely cultivated in temperate regions. It is a low perennial, hairy herb with a branching rhizome, and rather numerous stems, most of which are short and bear leaves only. The flowering stems are long, slender, prostrate, often rooting at the base, but ascending and branched above, and bearing the flowers at the ends of the branches. Flower-heads radiate, about 2 cm. (⅘ in.) across, with, in the "single" (natural) form, a single row of white rays and a yellow disc. Involucre of two or three rows of blunt, appressed, scarious-margined scales. Receptacle chaffy, conical, solid, longer than broad; ray flowers fertile, limb three-toothed; disc flowers perfect, tubular below, bell-shaped above. Achenia obovate, slightly compressed, pappus none. The oil glands are mostly on the corolla tubes, and less abundant on the ray than on the disc flowers.

The plant is a native of Europe, and is largely cultivated in temperate regions. Under cultivation, ligulate flowers largely replace the tubular disc flowers, so that the heads become "double" and large and white, which condition, by careful and rapid drying, should be preserved in the dried heads.

Chamomile contains nearly one per cent. of a blue volatile oil, turning greenish or yellowish with keeping and having a specific gravity of .905 to .915. The important constituents of this oil are *anthemol* ($C_{10}H_{16}O$) and *cumin aldehyde* (C_6H_4,C_3H_7,CHO). The composition of the remainder of the oil is very complex. With the oil there are an amaroid, some resin, and a little tannin.

Chamomile is one of the very best of the aromatic bitters, and is strongly carminative and somewhat antispasmodic. The dose is 1 to 4 gm. (ʒ ¼ to i.). There is no official preparation. The best form of administration is a tincture, so as to contain all the oil. As a simple stomachic a decoction or infusion is excellent. This should be well diluted, taken slowly before meals, and the dose should be small. The oil is often given as a carminative and antispasmodic, in doses of ♏ i. to v.

Allied Plants.—The genus contains about eighty species, and includes the common mayweed (*Anthemis cotula* Linn.). They are generally less agreeable than chamomile, and although of similar qualities, not in use. *Chrysanthemum parthenium* Pers. (Feverfew) is sometimes used as a substitute or adulterant of this article. It can be told by its flatter and less chaffy receptacles.

Henry H. Rusby.

CHAMOMILE, GERMAN.—*MATRICARIA.* "The flower-heads of *Matricaria Chamomila* L. (fam. *Compositæ*)" (U. S. P.). This drug is the product of a daisy-like plant, one to two feet in height, native of Europe and Western Asia, and introduced, as a roadside weed, into many countries. The reflexed rays are about fifteen in number, nearly half an inch long, white, three-toothed. These rays, together with its elongated, conical, and hollow receptacle, which bears no scales, distinguish it from all drugs or substitutes which might be mistaken for it.

Its active constituents are its anthemic acid, which is very bitter, and less than half of one per cent. of a dark blue volatile oil. There are also a small amount of tannin and some anthemidin.

The drug is very largely used as an ingredient of proprietary "teas" and other herb mixtures, but possesses only ordinary aromatic-bitter properties of the *Compositæ*, which see. The ordinary dose is 1 to 4 gm. (gr. xv. to lx.), and it is commonly given in infusion or fluid extract. *Henry H. Rusby.*

CHANCRE. See *Syphilis.*

CHANCROID.—Chancroid is a local, contagious, venereal disease, appearing as suppurating ulcers about the genitals, and is due to contact with secretions from the same kind of ulcerations. Aside from causing more or less severe inflammatory reaction in the lymph glands in the immediate vicinity of the sores, chancroid is always a local process and never causes constitutional infection.

Until within the last half-century it was generally believed that syphilis and chancroid were due to the same cause, but their individual entity has now so long been established that the old opinions interest us simply as a matter of history. The two diseases very frequently exist in the same individual at the same time, but they are, of course, due to inoculation at the same time and spot with two entirely separate and distinct poisons.

At the outset too much emphasis cannot be placed on the necessity of a careful examination and accurate diagnosis of all venereal sores. Cases of initial syphilis are constantly being diagnosed as chancroids. Many men have married with their doctor's approval (and reassurance that their sore was a soft one and therefore harmless), only to see syphilis appear in themselves and be transmitted to their wives and children.

To the clinical observer the purulent secretion from chancroids is the medium which conveys the contagion, and it has been claimed that the leucocytes alone contain the virus, and that inoculations with a solution from which the pus cells had been removed yielded negative results. We also know that cold has apparently little effect upon the vitality of the organism, while it is readily destroyed by heat, drying, and antiseptics.

Etiology.—Chancroid is undoubtedly due to a specific micro-organism, but what that organism is has not yet been conclusively demonstrated.

At the present time there are only two opinions that are deserving of consideration: first, the claim that the ordinary pyogenic bacteria are capable of producing typical chancroidal ulcers; second, that the bacillus of Ducrey is the pathogenic organism. It has also been claimed that cases of chancroid have arisen *de novo*, there having been no active chancroidal ulcerations present in the party giving the infection.

In asserting that chancroids are of purely pyogenic origin, it has been pointed out that the secretions from chancroids always contain streptococci, staphylococci, and non-pathogenic bacilli, as well as the streptobacillus first described by Ducrey and claimed by him to be the specific organism of chancroid. It is also claimed that chancroid is to mucous membranes what impetigo and pus infection are to the skin, and that the streptobacillus is an accidental accompaniment and not the cause; and, furthermore, that chancroid is usually found in broken-down prostitutes and among the poorer classes in general, a class whose vitality is lowered by lack of proper food, over-indulgence in alcoholics, by filth and unhygienic surroundings; in other words, a class in whom we know that slight abrasions of the skin become easily infected with pus cocci, suppurate freely, and do badly in general.

Certainly the genitals in the uncleanly, with heat, moisture, and decomposing smegma, furnish an excellent medium in which the pus organisms may grow.

Now it is well known that chancroid is by no means confined to the cachectic and debilitated, but may occur in the robust and healthy when exposed to chancroidal infection. If pyogenic bacteria alone were capable of causing chancroids, those individuals with long foreskins and excoriative balanitis, with acquired phimosis and a foul subpreputial discharge, would develop chancroids. Furthermore, women with peri-urethral or vulvo-vaginal abscesses, complicating gonorrhœa, or men with ulcerations dependent on scabies of the genitals, would also develop chancroids. Clinical experience shows that such is not the case.

It was pointed out by Ducrey that in repeated inoculations with chancroidal pus the accompanying streptococci, staphylococci, and other bacteria rapidly disappeared, leaving nearly pure cultures of the streptobacillus, which he looks upon as the pathogenic organism of chancroid. Unna, Krefting, Wielander, and others have found, both in smear preparations and in sections from the floor and walls of chancroidal ulcers, these same bacilli described by Ducrey.

They are short and thick, with rounded ends, and have a slight constriction in the middle which gives them a sort of figure-of-eight or dumb-bell appearance, and tend to group themselves in parallel chains. The bacilli usually lie outside the cells, though occasionally within them, and they are said not to be found in the pus of suppurating chancroidal buboes. The bacilli of Ducrey stain readily with fuchsin or gentian violet, and are decolorized by Gram's method of staining.

Bacteriological investigation is handicapped by the inability to grow the bacilli on artificial media, and also from the fact that up to the present time animals have not been successfully inoculated.

Until these bacilli can be cultivated and inoculations made producing characteristic lesions, and from these lesions the organisms recovered, the claims for the Ducrey bacillus cannot be accepted as conclusive.

Clinical History.—There is no period of incubation in chancroid. The process begins as soon as the virus gains an entrance to the tissues, and usually is noticed within two or three days after exposure.

The first thing that appears is a small papule with a yellowish centre situated on an inflammatory base and surrounded by a slight halo of congestion. The yellow vesicle in the centre increases and soon ruptures, leaving a small ulcer with a grayish, velvety base and sharp, well-marked edges, giving it a punched-out appearance. The edges become undermined and give way, and the size of the ulcer increases in this manner, the surrounding congestion spreading as the ulceration advances. The floor of the ulcer then has a grayish, uneven, worm-eaten appearance, is bathed in pus, with little tendency to bleed, unless roughly handled. There may be only one ulcer at the start, or there may be several, but soon fresh points of auto-infection appear and each new ulceration goes through the stages of destruction, rest, and repair like its predecessors. This tendency to spread by auto-inoculation is one of the most striking and constant of the characteristics of chancroid. The floor and edges of a chancroidal ulcer, no matter how long it has existed, are never indurated unless it has been cauterized.

Within a short time after the appearance of chancroidal ulcerations the glands in the immediate vicinity may become inflamed. Usually but a single gland in the chain swells, becoming both painful and tender, but the glands in both groins may become affected. Not infrequently the glands break down and require surgical care.

In trying to determine the character of a doubtful sore, great care should be taken to notice the condition of the neighboring glands, for their behavior in chancroid is so entirely unlike the condition in syphilis that it is one of the chief features in diagnosis.

In chancroid the glands are either not affected at all, or when affected, are inflamed, painful, and tender, and tend to suppurate, while in syphilis the process is non-inflammatory, the glands are neither painful nor tender, and they very rarely undergo suppuration.

In men with long foreskins soft chancres situated on the mucous membrane of the prepuce or along its free margin often cause an acquired phimosis with a good deal of heat, redness, swelling, and pain. The whole prepuce then feels thickened, brawny, and tender, and may entirely obscure the beginning induration of a sore beneath, so that in this condition one should be very guarded as to the outcome of such a case. When the ulcers are seated about the ostium preputii, micturition is usually painful, as the urine comes in contact with the raw surfaces. This pain may be greatly relieved by urinating with the penis immersed in warm water.

It is not uncommon to find the lymphatics running along the dorsum of the penis inflamed and tender, and occasionally a gland at the base of the penis swells and may even suppurate.

Location.—Chancroid is usually located about the genitals. Extra-genital chancroids do occur, but are very rare as compared with the extra-genital initial lesions of syphilis. In men the most common site of chancroids is in the sulcus, back of the corona glandis, next the frænum. Here minute tears occur from mechanical violence during intercourse and are readily infected.

Ulcerations in this location are more painful and tend to bleed more easily than in other spots. They also frequently perforate and destroy the frænum entirely. The resulting ulcers are slow to heal and may give rise to a good deal of hemorrhage, owing to the abundant blood supply.

Another common spot is along the free margin of the prepuce. Here the ulcers are irritated in handling the penis in urinating, in retracting the foreskin for purposes of cleanliness, etc.

In women the lesions of chancroid are situated about the clitoris, introitus vaginæ, and on the labia, perineum, and about the anus; very rarely on the cervix uteri or the walls of the vagina.

When extra-genital chancroids do occur, it is usually by auto-infection rather than by direct infection; *e.g.*, a careless patient in caring for his chancroids may smear some of the discharge on his fingers and inoculate some part of his integument by scratching.

The number of lesions in a case of chancroid is variable; it may remain as a single sore, but is usually multiple, the multiplicity being due to the highly inoculable character of the chancroidal pus. The virus can undoubtedly penetrate sound mucous membranes when deposited thereon, while on the skin entrance is gained through hair follicles or minute abrasions.

The power of reproducing itself in the same individual is perhaps best shown in the case of filthy women who allow the discharges from chancroids about the vulva to run down over the perineum and about the anus, or even the upper part of the thighs, thus causing very numerous ulcerations in the localities named.

In determining the character of a doubtful sore, it is sometimes of value to try auto-inoculation. In doing this a spot well removed from the large chains of lymph glands should be selected. The pus from chancroids is always capable of auto-inoculation.

The size of chancroidal ulcerations varies from that of a pea in mild cases up to a silver dollar or larger in severe serpiginous cases. The size of the lesion is of comparatively little value in making a diagnosis. The shape of the ulcer is perhaps oftener roundish or oval, but this depends upon the location and is of no importance.

The duration of the disease is modified so much by the patient's general physical condition and habits of life, as well as by the medical management of the case, that it is difficult to give anything like an exact time limit.

There are three fairly well-marked stages in the disease: the period of destruction, followed by an interval in which the condition remains about stationary, the ulcerations not extending; and this in turn is followed by the period of repair, where the character of the ulcer changes;

it appears less sluggish, bright red granulations begin to show in the floor of the ulcer, and there is then a greater tendency to bleed; any necrotic tissue which may be present comes away and the sore heals by granulation. In uncomplicated cases in otherwise healthy individuals, the course is run in from two to six weeks. Too vigorous exercise, alcoholic indulgence, and complications such as phimosis, gangrene, or phagedæna (the two latter are very rarely seen at the present time), may extend the course much longer.

Diagnosis.—Chancroid is to be differentiated from the initial lesion of syphilis, from the mucous patches of secondary syphilis and the gummatous ulcerations of late syphilis, from herpes progenitalis, from ulcerations accompanying scabies of the genitals, and from epithelioma.

The initial lesion of *syphilis* is to be distinguished from chancroid by its well-marked period of incubation, the sore usually appearing in from two to four weeks after exposure. Instead of a suppurating ulcer we are apt to find a more or less well-marked infiltration of the tissues about the sore with an erosion of the surface, and with very little purulent secretion. The striking features of chancroid are the non-indurated, suppurating ulcers which are always capable of auto-inoculation. In syphilis, on the other hand, we are impressed by the induration (the sore often feels like a foreign body in the tissues when taken between the thumb and fingers), and by the fact that the number of sores, representing so many points of inoculation, always remains the same from the beginning to the end.

Another important difference is the behavior of the neighboring lymph glands in the two diseases. It has already been pointed out that usually in chancroid a single gland in the chain is swollen, painful, and tender, and the process not infrequently ends in suppuration. In syphilis the glands in the whole chain are affected, are non-inflammatory, neither painful nor tender, they are freely movable under the fingers and have a peculiar hard, shotty feel. It is rare for the glands accompanying the initial lesion to break down.

In a case of chancroids one can never rule out the possibility of a coexisting syphilis until the incubation period of the latter is past.

In women especially, mucous patches of syphilis occurring about the vulva and anus may very closely simulate chancroids. The same lesions are found in men usually about the glans penis. These lesions will be found to have not the clean-cut edges, purulent secretion, or the velvety, worm-eaten-appearing base of chancroids, but a grayish, smooth, opaline appearance. The secretions from these mucous patches are highly contagious and foul-smelling, but are never capable of auto-inoculation.

The diagnosis, in the case of mucous patches, can generally be easily determined by the presence of other syphilitic manifestations or by the history.

At times a late syphilitic ulcer may appear about the genitals and very closely simulate a chancroid. The history of a previous syphilis, the non-involvement of the glands in the vicinity, and the lack of evidence of auto-infection will hardly allow a mistake to be made.

Herpes pregenitalis.—In herpes there is a sense of burning and itching before the eruption appears. At first the contents of the vesicles are clear and not yellow like chancroids, though they may become yellowish later, when pus is present. The covering of the vesicle easily ruptures and the small ulceration resulting may extend somewhat in depth, but not in breadth, unless two or more vesicles run together. There is seldom any disturbance in the lymph glands and the disease runs a self-limited course. The spots dry up and disappear in a week or ten days There is often no history of exposure, and certain individuals are prone to repeated attacks. It occurs in both sexes, and it is not very uncommon to see a person with a herpes progenitalis and a herpes labialis at the same time.

Ulcerations about the genitals due to *scabies* are to be distinguished from chancroid by the presence of burrows and marks of scratching on the foreskin, and evidence of scabies on other parts of the body.

A *peri-urethral abscess* occurring in the sulcus, back of the glans, might at times suggest a chancroid, but if its sharply circumscribed appearance and inflammatory character are borne in mind, together with the history of a previous gonorrhœa, the liability of a mistaken diagnosis is very small.

Complications.—The complications of chancroid are phimosis and paraphimosis, lymphangitis and suppurating bubo; phagedæna and gangrene are very rarely seen nowadays.

Phimosis and *paraphimosis* not infrequently occur during the course of chancroid. In phimosis the whole prepuce may become swollen, red, or reddish purple in color, tender and doughy to the touch, with a more or less profuse foul, purulent discharge.

Often there will be one or two small ulcerations at the margin of the foreskin which show the nature of the sores within. Occasionally, in unrelieved cases, the prepuce ulcerates through and allows the glans to protrude. Paraphimosis is less common, though not much less severe a complication. The swelling of the parts may be very great, and the line of ulceration which occurs in the line of constriction back of the œdema, at right angles to the shaft of the penis (nature's attempt at relief of the condition), becomes infected with the chancroidal virus and extensive destruction of tissue may result.

Lymphangitis and Lymphadenitis.—As has already been mentioned, the lymphatics of the penis are often involved and are felt as a hard, tender cord beneath the skin.

The condition of the lymph glands has already been described.

Treatment.—In the treatment of chancroids it is essential that the patient keep as quiet as possible. All excessive or violent exercise, running, skating, dancing, etc., is to be avoided.

The next step is to keep the sores thoroughly cleansed with soap and water and antiseptic solutions. It is always well to use the lotions as hot as is grateful to the patient, for heat in itself is exceedingly beneficial in the treatment. The principal solutions in use to-day are corrosive sublimate, 1 to 1,000 or 1 to 2,000; creolin, 1 to 250; lysol, 1 to 500; formalin, 1 to 50; carbolic acid, 1 to 50; boric acid in saturated solution. After cleansing with the wash, the surface of the ulcers should be carefully dried and dusted over with one of the following powders: aristol, europhen, iodol, calomel, acetanilide, or iodoform.

Perhaps the last named is the most efficacious of any of the powders named for use in the early stages or up to the appearance of healthy granulations. Of course its odor is a great objection, and its use is as a promotor of healthy granulations. It should ordinarily be used as a fine powder, but may be suspended in ether or glycerin. The deodorized iodoform is of little value. Care should always be taken not to irritate the sores, either by manipulation or by the dressings employed.

This may be termed the conservative or symptomatic treatment; opposed to this may be given the heroic or radical treatment.

Here the attempt is made to change at once the chancroidal ulcer into a simple one by thoroughly destroying the surface of the sore. This is usually accomplished by the actual cautery or by the application of caustic acids. Nitric and carbolic are the ones commonly used to-day. Excision should rarely, if ever, be done. Before cauterizing a sore it should be carefully cleansed and cocainized, and then the acid applied thoroughly to the floor and edges of the ulcer, with a bit of absorbent cotton wound around the end of a wooden toothpick. Care must be taken to restrict the action of the acid to the diseased tissue, and the action of nitric acid can be controlled by the use of bicarbonate of soda.

The stick of silver nitrate is a popular caustic with the laity, but its use is to be severely condemned. Its action is superficial, irritating to the tissues, productive of œdema and suppurating bubo, and should never be employed as a means of destruction of the sore, but as a stimulant to sluggish granulations it may be of service. However, it should never be used early. Caustics should never be applied to a sore that cannot be thoroughly exposed and properly cared for. After cauterizing, the sore should be treated with moist bland dressings for a time, lint soaked in lead-water wash or a solution of boracic acid or black wash, and changed frequently. After a few hours this dressing should be changed to one of the powders already named.

As a general rule, ointments and greasy preparations should not be employed, except, perhaps, over the powder to keep the cloth from sticking and thus prevent bleeding when the dressing is changed, or when the ulcer is granulating, to promote healing. Internal medication, unless the individual is much run down, is not usually needed. General tonics (iron, cod-liver oil, syrup hypophosphites, etc.) may often be of service in debilitated cases.

Mercury should never be given in a case of chancroid.

In old sluggish chancroidal ulcers, a thorough curetting is sometimes of service. In women the treatment is more difficult by reason of the inability to keep the parts clean and reach all the points of infection. Hot injections of soap and water or borax and water followed by a corrosive douch, 1 to 5,000, should be used once or twice daily, and one of the powders already mentioned dusted on all the available spots.

A ten to forty per cent. solution of formalin gently applied, or a saturated solution of pyoktanin blue, has been highly recommended in sluggish cases.

In general, it is always advisable, in the vast majority of cases, to avoid using any sort of caustic. When used, it should be applied only to carefully selected cases, and should be used with the greatest care.

C. Morton Smith.

CHANGE OF LIFE.—This term, in common use, signifies the series of phenomena which are apparent at the end of the child-bearing period.

It is applied exclusively to women, though an analogy has been observed between some of the conditions which affect women at the period in question and similar conditions which have frequently been noted in men at the time when their physical powers have reached their culmination.

The term which is generally accepted and used by medical writers as correlative with *change of life* is *menopause*.

This term is sufficiently explicit for only one link in the chain of phenomena which comprise the *change of life*, to wit, the cessation of the monthly flow. For this reason the common term is the more exact and comprehensive and therefore presents claims for its general use.

The *change of life* is really one of the great epochs in the life of woman, for it not only serves as the boundary line between the period in which she is able to reproduce herself and her species—period of fruitage,—but it marks the limit of the progressive stage of her physical condition in general, deterioration being henceforth the prevailing process, whether it develops slowly or rapidly.

Time of its Occurrence.—Like all the other functions of animal life, this one also is subject to great variations both as to the time of its occurence and the events which characterize it.

According as it occurs early or late in life it may be premature, normal, or retarded, and it may be natural or artificial according as it is or is not solely the product of physiological forces.

In temperate climates we may expect its appearance in the majority of cases between the fortieth and forty-fifth years; family or race peculiarities may advance it two or three years or defer it for an equal period. It is premature when it occurs prior to the fortieth year and it is retarded when it occurs later than the fifty-fifth.

Influences which Modify its Occurrence and its Course.—*Race.* The nearer a tribe or race of human beings approaches the lower animals in its intellectual development the less marked will be the menstrual function in its women.

Menstruation is quite clearly the development or evolution of the *rut* or *œstruation* in the lower animals. In the apes and monkeys we observe very frequently a distinct regularity in what may be termed *for them* the menstrual flow. Neither in the animals nor, so far as my knowledge extends, in the lower orders of human beings are there well-defined conditions which might constitute the *change of life*, at least as this experience is observed in the more advanced races.

In proportion as a community or race advances in civilization do we see the menstrual function and the *change of life* assume distinctness and character. While it does not follow that their unusual or pathological features are necessarily the result of civilization, since there are countless examples in which no appreciable disturbance is experienced from either, it is certainly true that such disturbance does accompany civilization.

Climate. The influence of extremes in temperature acts upon the *change of life* precisely as we would anticipate. In the tropics vegetation is luxuriant, matures early, and is profuse in its fruitfulness, but the duration of its life is shortened by the very excess of this profuseness. It is the same, to a certain extent at least, with human females who are native to the tropics; they mature and bear their children early, and in frequent instances reach the menopause between twenty and thirty. This has been observed especially of the Arabs of the desert. To the Caucasian races transplantation to the tropics means a distinct lowering of vitality, with a great diminution in reproductive power and a consequent tendency to the early cessation of the menstrual function, and the advent of the change of life. In the Arctic regions the effect of extreme cold upon vitality is similar to the effect of extreme heat, though it may be made endurable to a greater degree than the latter. The natives of the Arctic regions are stunted in form and more or less deficient in vitality. This is especially the case after they have endured the rigors and the darkness of the long Arctic night. The women seldom mature earlier than the twentieth year, menstruate very infrequently, and seldom have more than one or two children. The duration of life is not great, and the *change of life* comes between thirty and forty.

Altitude. The significance of this factor is due, of course, to the change in the air pressure. Women may gradually become habituated to any condition of atmospheric pressure, but the effects which obtain prior to such habituation are very distinct. A change to the sea level by one who has lived away from the sea and at more or less of an elevation generally suspends or otherwise disturbs the menstrual flow, and in cases in which there is decided constitutional disturbance it is possible that the *change of life* might be hastened by such residence.

Those who go from the sea level to reside at altitudes of six thousand to seven thousand feet or more experience, on the other hand, increased profuseness in the menstrual flow, the external air pressure being greatly reduced. Of the influence of such reduced pressure upon the *change of life* except in prolonging its duration and increasing the frequency and profuseness of its hemorrhages, I am not prepared to speak. I know of no statistics bearing directly upon this subject, which is one of the many fruitful themes in climatology still awaiting investigation.

General Physical Condition.—The general condition of a woman has much to do with the inauguration of the *change of life* and with the events by which it may be characterized. Those who suffer with grave constitutional and visceral diseases which seriously impair their vitality are almost certain to experience an arrest of menstruation and often other symptoms which accompany the *change of life.* Those who suffer with tuberculosis, syphilis, general anæmia, chronic diseases of the liver or kidneys, etc., are in this category. The acute wasting diseases sometimes produce so profound an impression that the menstrual function is entirely obliterated. On the other hand, the malignant diseases of the genital organs, if present at a time when the change of life might be expected, cause its unlimited delay. I do not recall a case of such disease, in a very large experience, in which the *change of life* ensued after the malignant disease had begun its destructive career. In fibroid tumors of the uterus, especially those which are characterized with much discomfort and hemorrhage, it was formerly the custom to hold out the hope that all trouble would cease when the *change of life* brought its beneficent issue. In most cases this has proven the most unsatisfactory will-o'-the-wisp hunting by which a poor mortal could be deluded. The *change of life* again and again escapes the grasp, until finally it comes to mean that transformation which arrives for us all "when this mortal shall put on immortality."

The beneficent influence of modern gynæcology has removed the veil of ignorance in regard to this subject, and the early removal of these tumors has alike brought on the *change of life* and the relief of many troublesome symptoms. The *change of life* comes quite early in women who become excessively fat. Such women are usually sterile. Their physical condition unfits them for the normal experiences of pregnancy and parturition, menstruation is infrequent, scanty, and painful, and it is not unusual for the *change of life* to occur within a few years of the appearance of the obese condition.

Surgical Procedures.—Certain surgical operations are conducted with the deliberate intention and purpose of bringing about the *change of life.* Such are all operations in which the ovaries are entirely removed. It is estimated that in ninety per cent. of cases of removal of the ovaries menstruation is at once arrested. If the uterus and Fallopian tubes are also removed the percentage in which such a result is obtained will be even greater. There are no other surgical procedures which act so directly to induce the change of life as does extirpation of the ovaries. Operations which may be followed by prolonged suppuration and invalidism by impairing the general nutrition and reducing vitality may result in arresting menstruation temporarily or permanently and in bringing about the premature appearance of the *change of life.*

Occupation.—Both a direct and an indirect influence may be exerted by occupation upon the subject which is under consideration. Such occupations as keep a woman in an elevated temperature during most of the day are very disturbing to the menstrual function, have a very decided tendency to produce obesity and may induce the *change of life* prematurely. Cooks, laundresses, and bakers are particularly subject to such influences. Other occupations which impair nutrition and vitality also disturb the menstrual function and hasten the *change of life.* Workers in chemical factories and laboratories upon arsenic, copper, lead, phosphorus, and other poisonous substances, workers in mines, cellars, in badly lighted, badly ventilated, and damp surroundings are included in this category. Other sufferers are those whose work is exhausting and unwomanly and predisposes to wrinkles and premature old age; such are fishwives, field workers, bearers of heavy burdens on the shoulders or head, mechanics' assistants who may carry tubs of mortar, casks of water or other heavy burdens, all these being types of laborers which one sees much more frequently among the laboring classes in Europe than in this country.

Excessive Fertility.—With many women the reserve capital of vital force is not large. Bearing children in rapid succession until five, six, or more have been borne in as many years exhausts that capital, and then follows the *change of life* while the woman is yet young. The reason for this is perfectly plain and is seen in the results which follow over-productiveness in animal or vegetable life wherever we may take the trouble to investigate it. Such a result can hardly be regarded as disease, but simply as the taking up of a certain amount of capital to which nothing remained to be added by way of replenishment.

Dissipation and Vice.—The number of women who lead irregular and vicious lives is so great that it would seem as if important deductions might be made from the study of such lives. It has happened to my experience to see quite a large number of women of the vicious and depraved class of all ages. These women suffer greatly both with acute and chronic diseases of the pelvic organs; they frequently suffer with profuse hemorrhage from the uterus, and their excesses very often result in sterility, so that if the vicious life is followed by marriage, it is not likely to be a fruitful marriage. It has been a matter of surprise to me, again and again, that the excesses in sexual intercourse on the part of prostitutes and others do not arrest menstruation and bring on the *change of life.* Of course irregular habits, late hours, excesses in alcohol, etc., frequently break down the health, and the menses may be arrested as the result of anæmia, etc., if the woman does not die promptly from exhaustion or some acute disease, as is the result with many. As a matter of fact I have seldom been called to record such an occurrence; indeed, the stimulation of the sexual organs and the careless, irresponsible life of many of these women seem to improve nutrition, and for a long time, at least, their physical condition is surprisingly good.

Phenomena and Duration.—There are certain phenomena which are almost invariable and others which are only occasional to the *change of life.* We must also remember that with some women the transition is immediate and without appreciable symptoms, except that the ordinary monthly flow abruptly ceases. The leading symptoms are practically the same whether the condition is the natural change or one which is induced by disease or surgical procedure. To those who experience it while still far removed from the usual period of time when it is to be expected, the symptoms may be exaggerated; but not necessarily so, for I have seen young girls go through this change with scarcely any discomfort or unusual happening.

Cessation of the Menstrual Flow.—The leading symptom is the disappearance of the regular monthly bloody discharge. This cessation may occur abruptly, the flow appearing one month, disappearing the next and never reappearing. This may be explained by the fact that physical maturity has been reached, just as the fruit falls from the tree when it is ripe; or it may be the result of disease, of removal of the ovaries, of intense emotion, etc. If the cessation of the menses occurs in young women, the possibility of its restoration in due season must be considered. Instead of an abrupt cessation the flow may reappear at regular or irregular intervals, two months, four months, six months or longer, finally ceasing altogether after one, two, or three years.

Excessive Flowing.—A very marked feature in some cases, when the flowing has become irregular, is its profuseness. It was formerly thought proper to do nothing for this symptom on the supposition that it was simply a natural discharge. I have striven diligently for years to combat this view. Excessive loss of blood is always unusual, abnormal, and should be investigated and arrested. The condition of the uterine mucous membrane usually calls for active treatment in such cases by the application of astringent substances to it or the removal of granulation tissue, which may be the cause of the hemorrhage, by the curette. Tumors and other disease of the uterus assume particular importance at this time, and one should never leave to the unaided efforts of nature the disposal of a burden at this time which she may be unable to dispose of or only with great risk to the patient's life.

Flushing and Other Vaso-Motor Disturbances.—Almost as common a symptom as the arrest or irregularity of the menses is the vaso-motor disturbance which occurs without warning many times a day until toward the end of the change, and is manifested now by flushing and heat, and now by pallor and chill. The experience of each paroxysm may continue but a moment, but it is annoying and in some cases depressing and weakening. What should cause this peculiar vaso-motor influence, now paralyzing and again stimulating the vascular system, can be only a matter of conjecture. It is an experience which is so universal that it may be regarded as not far removed from the physiological. It is one of the first symptoms which occur, it continues two or three years, and by that time it has become endurable by its very frequency. With some women it continues uninterrupted to the end of life. It seems to make no difference whether the menopause is natural or induced as to the frequency and intensity of this symptom. It may be expected, however, that with those to whom the change comes early in life it will continue longer, as a rule, than with those to whom it comes as an entirely natural experience.

Mental and Nervous Phenomena.—One of the many notions concerning the *change of life* which formerly prevailed was that since it was a *critical* time all sorts of unpleasant things might be expected to develop in connection with it. If a woman became crazy at that time it was the *change of life* which did it, and it was more than likely that she would become crazy if she had any predisposition or predilection to mental instability.

The arrest of the menses and the disturbance of the blood tension undoubtedly may cause brain disorder in those who are predisposed to such trouble, and this may vary in its manifestation between headache and violent delirium terminating in mania or melancholia. Many women are *queer* or unusually hysterical at this time, neuralgias of all varieties are frequent, insomnia is not infrequent, and a disposition which has heretofore been amiable may be suddenly or gradually transformed into one to which the most unusual or grotesque desires or actions are possible. The outbursts in such cases should not all be attributed to the *change of life*, they are due in part to the previous inheritance of the individual and in part to the tissue changes which take place. Besides, the great majority of women have none of these experiences at all, so that they must be considered exceptional and not a customary accompaniment.

Changes in Nutrition.—Changes in nutrition are a noteworthy feature of this period, the active upbuilding time of life is over, and the tissues now and henceforth are less substantial. Muscular tissue tends to degenerate and atrophy, and fat is accumulated. This may lead to improvement in the general appearance and rounding of the figure, but it may also lead to grossness and obesity. Personal beauty is lost in some cases while an unusual attractiveness is acquired in others.

This period and the remaining years of life being the era of degeneration, it is not strange that cancer of the breast, the womb, and other genital organs should be found at this time more frequently than in earlier life. Cancer is not necessarily a feature or customary accompaniment of the *change of life.* This is a fact which I have insisted upon for years in spite of a prevalent opinion to the contrary, both in the profession and in the laity. It frequently coexists simply because the *change of life* stands at the entrance of the degenerative period. We look for cancer in men in its greatest frequency at the same period of life that we look for it in women; the ending of the child-bearing period and the cessation of the menses must therefore have little to do with the development of malignant disease.

Disturbances in Various Organs of the Body.—These have been frequently noted, and in a book which was written by me upon this subject ("The Menopause," D. Appleton and Co., 1897) various complicating affections have been alluded to. It has always seemed to me very necessary that one should carefully distinguish those complications which merely coexist from those which cause or are caused by the *change of life.* Dimness of vision has been reported as an accompaniment in many cases, also liver engorgement or other derangements in efficient working power of the kidneys and urinary bladder, loss of appetite, indigestion and constipation, rapid action of the heart and dyspnœa. These, it will be observed, are all functional disturbances, and it is such rather than organic lesions of which the change of life is most likely to be the cause.

Impregnation after the Change of Life has Occurred.—The question is an interesting one, and it has often been asked whether impregnation could occur after the menstrual flow had entirely ceased. This question may be regarded as entirely settled, indeed it may be said that impregnation has very little to do with the menstrual flow or the menstrual flow with it. It is said that the Esquimau women are impregnated customarily before the menses have appeared. Many instances have been observed in which a similar event has occurred in our own latitude before the appearance of the menses. The facts in regard to impregnation after the menses have ceased and the *change of life* has been concluded are equally authentic and definite. It is not usual for such an event to occur, but it does occur occasionally. It is believed that the ovaries continue their functional activity from the beginning till the end of life, and in not a few instances pregnancy has taken place many years after it was supposed the child-bearing function had ended. I am personally familiar with cases in which this interval has been ten to fifteen years, women from fifty to fifty-five years of age giving birth to healthy children. Equally strange are those cases in which pregnancy occurs when both ovaries have been removed. I know of two such cases reported by reputable and talented men. Either the ovaries were not entirely removed, or there was a supernumerary ovary, or there was some hidden cause which cannot be explained.

Andrew F. Currier.

CHANNEL ISLANDS. See *Guernsey.*

CHARCOAL.—The essential constituent of charcoal is the element carbon, which, as it occurs in charcoal, presents itself as a black substance, insoluble, infusible, odorless and tasteless. The medicinal virtues of carbon reside solely in the singular absorbent property of this element. As represented by the substance charcoal, carbon tends strongly to absorb and hold fast gases and many organic principles, notably alkaloids and odorous and coloring matters. And in the case of such of these bodies as are oxidizable, the fact of their retention in the meshes of the charcoal mass leads to their ultimate chemical transformation by oxidation. Charcoal thus operates indirectly as an oxidizing agent, and thus is practically available as a decolorizer, deodorizer, detergent, and, so far as noxious *products* of zymotic processes are concerned, also as a disinfectant. Charcoal is used by the pharmacist to decolorize and to separate organic principles, and by the physician to deodorize and hasten oxidation in the contents of receptacles for excreta, to deodorize foul discharges, and, given internally, to absorb and hold the substance of vegetable poisons, such as alkaloids, until their evacuation can be determined, and, by absorption and secondary chemical conversion, to dispose of the noxious products, fluid and gaseous, of fermentation of the ingesta in a dyspeptic stomach.

Charcoal is official in the United States Pharmacopœia in the following forms:

Carbo Animalis, Animal Charcoal. Under this title is recognized the common so-called animal charcoal or *boneblack*, that is derived as a black pulverulent residue from the heating of bone to redness in a closed vessel. Animal charcoal occurs in "dull black, granular fragments, or a dull black powder, odorless, nearly tasteless, and insoluble in water or alcohol. When ignited, it leaves a grayish or yellowish-white ash, amounting to about eighty-five per cent. of the original weight of the portion taken" (U. S. P.).

Animal charcoal is official as the basis for the following preparation:

Carbo Animalis Purificatus, Purified Animal Charcoal. Animal charcoal, in No. 60 powder, is digested with diluted hydrochloric acid on a water-bath for many hours, and the undissolved residue then freed from the acid by thorough washing with water, dried, and put up in well-stoppered bottles. By this procedure the calcic salts, which form so large a proportion of the weight of crude animal charcoal, are dissolved out, and the carbon is thereby obtained practically pure. Purified animal charcoal is "a dull black powder, odorless, tasteless, and insoluble in water, alcohol, or other solvents" (U. S. P.).

Probably because of a peculiarity of its texture, animal charcoal decidedly surpasses wood charcoal in the property of decolorizing and of separating and holding vegetable principles. It is, therefore, the form of charcoal most used by the pharmacist, and should be selected also by the physician where the purpose is to withhold swallowed vegetable poisons from absorption. But in this application it should be remembered that the action of the charcoal is, so to speak, mechanical only, and the use of the same, therefore, should be merely accessory to measures to secure evacuation. The charcoal should be given freely, by the spoonful, in suspension in water, until from half a tumblerful to a tumblerful shall have been taken.

Carbo Ligni, Charcoal. Under this title is recognized officially "charcoal prepared from soft wood and very finely powdered." When well prepared, wood charcoal contains but a very small percentage of mineral matter, and, therefore, may be regarded as practically all carbon. For medical purposes it is pulverized, and yields an exceedingly fine, light, black powder, odorless, tasteless, and insoluble. Upon exposure it attracts moisture, and it is in best condition, therefore, when freshly made. It should be kept in tightly closed receptacles.

Wood charcoal possesses in high degree the property of absorbing gases of certain kinds, and notably the foul-smelling products of zymotic processes. For deodorizing purposes it may be relied upon to absorb and effect the decomposition of from fifteen to twenty times its bulk of gas. It thus makes a good application to privy vaults or cesspools, a pailful of powdered charcoal, as freshly made and as well preserved from damp as possible, being thrown into the receptacle once or twice a week. To wounds or sores yielding offensive discharges charcoal may be applied by dusting upon the surface, by strewing upon the face of a poultice, or by quilting the powder between two layers of cotton wadding, such quilt being then used as the wound dressing. In dyspepsia, with acidity and flatulence, relief often may be secured by administering powdered charcoal in quantities ranging from half a teaspoonful to a tablespoonful. It should be, if possible, freshly made, and is more effective if taken dry. Otherwise it is given mixed with water or milk. Charcoal should not be taken in large doses too frequently, for under such circumstances considerable mechanical irritation has been known to follow. In mild dyspeptic cases, quite small doses, such as from 0.12–0.30 gm. (gr. ij–v.) may be all-sufficient, and such quantities may be taken without objection.

A sample of charcoal that has lost potency by keeping recovers the same on being recalcined.

Edward Curtis.

CHARLESTON, S. C.—A city of 65,000 inhabitants, and one of the chief seaports of the South, situated upon a point of land between the mouths of the Ashley and Cooper rivers, several miles from the Atlantic Ocean. It is an attractive, old-fashioned town, with rich vegetation of a more or less semi-tropical nature. It is a convenient and interesting place to spend some time in, on one's way north from the more Southern resorts, especially in the spring. The magnolia gardens in the vicinity are most interesting and well worthy of a visit. Indeed, both by water and land the excursions are many and attractive. The writer recalls very vividly the delight of a visit here in the spring when returning from Florida. The mild balmy atmosphere, the profusion of roses, the jasmine, the strawberries, the quaint and attractive streets and residences, and the numerous excursions, were a constant source of pleasure.

As will be seen from the climatic table, the winter and spring climate is a mild, equable, marine one. The proximity of the sea renders the relative humidity greater than at the resorts farther inland; hence this is not a favorable climate for a permanent residence for the consumptive.

CLIMATE OF CHARLESTON, S. C. LATITUDE, 32° 47′; LONGITUDE, 79° 56′. PERIOD OF OBSERVATION, 12 YEARS 10 MONTHS.

Data.	January.	March.	July.	November.	Year.
Temperature (Fahr.)—					
Average or normal,	49.5°	57.8°	82.8°	57.2°	65.9°
Average daily range	14.6	15	14.1	14.1	
Mean of warmest	58.4	67.1	90.2	65	
Mean of coldest	43.8	52.1	76.1	50.9	
Highest or maximum	80	85	104	82	
Lowest or minimum	23	28	67	28	
Humidity—					
Average relative	75.4%	69.6%	74.3%	74.7%	73.8%
Precipitation					
Average in inches	3.77	4.47	7.18	3.51	59.9
Wind—					
Prevailing direction	N.	S.W.	S.W.	N.E.	S.W.
Average hourly velocity in miles	7.3	8.8	7.7	7.5	7.9
Weather—					
Average number of clear days	9.5	12.7	10.4	11.5	134
Average number of fair days	10.5	10.8	14.6	10.5	140.3
Average number of clear and fair days	20	23.5	25	22	274.3

Edward O. Otis.

CHARLESTON ARTESIAN WELLS.—Charleston County, South Carolina.

POST-OFFICE.—Charleston.

Several artesian wells in the city of Charleston have been found to be impregnated with mineral ingredients. Those mentioned in the Geological Reports are the "Old Artesian Well," the "Citadel Green Well," the "Commercial Cotton Press Well," and "Chisholm's Mill Well." We introduce the following analysis of the first of these, made in 1868 by Dr. C. U. Shepherd, Jr.:

OLD ARTESIAN WELL.

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Sodium bicarbonate	71.06
Calcium bicarbonate	.12
Magnesium bicarbonate	.02
Sodium chloride	63.38
Silica	Trace.
Organic matter	Trace.
Iron oxide	Trace.
Aluminum oxide	.79
Carbolic acid	Trace.
	135.37

This water has a temperature of 87° F., and is therefore a thermal. The well is 1,250 feet deep, and the flow of water is estimated at 1,200 gallons per hour. The Commercial Cotton Press Well contains a considerable proportion of sulphate of magnesium.

James K. Crook

CHATTOLANEE SPRINGS.—Baltimore County, Maryland.

POST-OFFICE.—Chattolanee. Hotel.

ACCESS.—Viâ Northern Central Railroad from Baltimore, 33 miles.

These springs are delightfully located in the Green Springs Valley. They are six in number and yield 1,500,000 gallons of water daily. The waters are not strongly mineralized, but are quite remarkable for their great purity and freedom from organic matter. The following analysis was made by Messrs. Lehman and Mager, of Baltimore:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Magnesium carbonate	1.81
Calcium carbonate	4.62
Magnesium chloride	.21

Solids.	Grains.
Sodium chloride	.11
Sodium sulphate	.08
Potassium sulphate	.10
Iron oxide	Trace.
Lithia	Trace.
Silica	.24
Carbonic acid (combined)	1.11
Total solids	8.28

Temperature of water at springs, 52° F.

The water is of the light alkaline-calcic class. In addition to its properties as a table beverage it is said to be very useful in dyspepsia and indigestion and the early stages of Bright's disease. The water is extensively sold in Baltimore and other cities. *James K. Crook.*

CHATTANOOGA, TENN.—A city of about 50,000 inhabitants, situated in the southeastern portion of Tennessee, upon the Tennessee River. It is 762 feet above sea level, and the surrounding mountains are from 1,320 feet—Missionary Ridge—to 2,160 feet—Lookout Mountain,—both of which points are easy of access. The scenery is varied and beautiful, and the atmosphere is exhilarating and pure. The spring is early, opening in March, and the vegetation rich and varied. The soil is dry and loamy, and the drainage good. There are occasional winds and fogs, but the city is so surrounded by mountains that it is greatly shielded in this way from the winds. The climate is indicated in the accompanying table, kindly obtained for the writer by Dr. W. A. Applegate, of Chattanooga. From this it is seen that the winter climate is moderate and the summer not excessively hot. The relative humidity is quite high, and the average number of clear and fair days not remarkably large in comparison with other health resorts in the South. The daily range of temperature is also seen to be large.

Chattanooga, Tenn. Latitude, 35° 4′; Longitude, 85° 15′. Climatic Data from Observations from 1879 to 1899 Inclusive.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Temperature, (Fahr.)—													
Average or normal	41.4°	45.4°	51.1°	61.0	68.5°	75.9°	78.4°	77.0°	71.8°	61.6°	50.3°	43.7°	59.9°
Average daily range	16	17.4	18.7	20.1	20.8	19.8	18.4	18	19.2	20.1	18.5	17.1	19.3
Mean of warmest	52.2	54.0	56.6	65.0	71.8	78.9	81.1	80.8	75.8	67.2	55.8	57.2	66.3
Mean of coldest	33.6	33.8	45.7	55.4	65.4	72.2	75.4	73.8	68.1	56.5	45.4	38.1	55.3
Highest or maximum	75	78	85	90	93	98	101	100	98	91	79	73	88.4
*Lowest or minimum	2	2	15	25	40	45	56	54	38	27	16	3	26.9
Humidity													
Average relative	76%	71%	67%	64%	69%	73%	75%	77%	76%	74%	71%	74%	74.2%
Precipitation													
Average in inches	6.19	5.32	5.95	4.52	3.89	4.49	4.22	3.80	3.70	2.71	3.71	4.31	52.81
Wind—													
Prevailing direction	N.E.	N.W.	N.W.	S.	S.W.	S.W.	S.W.	N.E.	N.E.	N.E.	S.	S.	
Average hourly velocity in miles	6.9	7.5	7.7	7.1	5.5	4.9	4.8	4.6	4.6	5.2	6.1	6.6	5.9
Weather—													
Average number of clear days	7	7	9	11	10	9	8	9	12	15	11	8	116
Largest number of clear days	12	13	18	18	19	16	16	15	21	23	22	14	207
Smallest number of clear days	2	3	4	5	2	4	2	5	5	8	6	1	47
Average number of fair days	11	10	11	12	15	15	16	15	12	10	9	11	147
Largest number of fair days	17	17	15	18	23	19	22	19	18	15	14	15	212
Smallest number of fair days	4	6	5	6	7	11	8	10	6	4	5	6	78
Average number of cloudy days	13	11	11	8	6	6	7	7	6	6	9	12	102
Largest number of cloudy days	22	16	17	14	13	15	13	13	12	13	15	17	180
Smallest number of cloudy days	7	8	4	3	1	1	1	3	0	3	3	8	42
Average number of rainy days	14	12	13	11	11	12	14	12	9	8	9	11	136
Smallest number of rainy days	9	6	7	6	5	6	6	5	2	3	3	5	63
Largest number of rainy days	24	22	21	17	16	19	19	18	16	13	19	17	221

* Lowest on record is — 10° on February 13th, 1899.

Judged from its climatic conditions solely, Chattanooga would hardly fall within the list of genuine health resorts, although, like so many partisan reports upon health resorts, its "climate conditions" are vaunted as "unsurpassed by any point in this country." It is needless to say that the writer who makes this statement gives neither full climatic tables nor any series of results obtained in the treatment of disease. Undoubtedly a residence in some of the high localities about the city offers, in the pure and bracing atmosphere, mild winter temperature, and attractive scenery, substantial climatic advantages in the treatment of pulmonary tuberculosis; for the chief end of all climatic treatment of consumption can well be accomplished here, namely, constant exposure to pure outdoor air. A sanatorium, for instance, on Lookout Mountain, conducted as Falkenstein or the Adirondack Cottage Sanatorium is, would doubtless exhibit equally good, if not better, results. Formerly malaria was very prevalent here, but since the sanitary condition of the city has been improved, this disease is said to have disappeared to a very great extent.

The outdoor attractions are many and varied; excursions to the various battlefields—Chickamauga, Missionary Ridge, Lookout Mountain, and Orchard Knob—are all full of interest. The view from Lookout Mountain, as the writer can testify from personal experience, is a striking one, looking down upon the winding river and the other lesser heights. The roads are good, and driving and wheeling are popular amusements.

The accommodations are excellent both as regards hotels and boarding-houses. "Lookout Inn" on Lookout Mountain is open all the year and affords the best of accommodations.

Chattanooga is a railroad centre and is easily accessible from all directions. *Edward O. Otis.*

CHAULMOOGRA.—Chawul-Mungri. The seeds of two species of *Gynocardia* (fam. *Flacourtiaceæ*) of Southeastern Asia; also the oil expressed from them and the bark, the latter not being an article of commerce with us. The seeds of commerce are commonly referred to *G. odorata* R. Br. This species, however, does not yield the ordinary seeds, which contain no prussic acid, but a different variety, rare in commerce and rich in prussic acid. The species yielding the commercial seeds appears undescribed, though it is indefinitely referred to by various authors. The bark employed is possibly that of the *G. odorata*, because prussic acid is developed in its infusion, which is also astringent, hence much like wild-cherry bark. It is used as a febrifuge. The fruit pulp is used to poison fish. The seeds and the oil expressed from them are extensively employed, externally and internally, in the East, as a remedy for leprosy and for various skin diseases.

The plant is a tree, and bears directly from its trunk and large branches, globoidal berries, as large as a shaddock, containing numerous seeds. The latter are about one inch or one inch and a quarter long, irregularly ovoid, angular from pressure, and dull gray. The kernel shrinks away from the testa in drying, the latter being thin and brittle. The oily kernel, at first white, becomes brown. It has a disagreeable odor and taste. The seeds consist of about half their weight of a brownish-yellow fixed oil, of a specific gravity of about .945. The active portion of this oil appears to be its 12 per cent. of gynocardic acid, with 2 of cocinic, 4 of hypogæic, and 60 of palmitic acids. The oil has been considerably employed in professional practice, both externally and internally, in skin diseases. The dose is ♏ iij.–iv. after meals, gradually increased. Doses of ♏ x. have been found irritating to most persons, resulting in vomiting and purging.

Gynocardic acid has also been employed and is said not to cause nausea. An ointment made of fifteen to twenty-five grains of this acid to the ounce of vaseline has been recommended as an application to dry patches of eczema.

False chaulmoogra is the seed of *Hydnocarpus anthelmintica* Pierre, a related plant. It is similarly used in native practice, and also as an anthelmintic.

Henry H. Rusby.

CHEILITIS GLANDULARIS APOSTEMATOSA. — Deriv.—*χεῖλος*, the lip; glandularis, having the appearance or form of glands; and apostematosus, from *ἀπόστημα*, an abscess.

Synonym.—Myxadenitis labialis.

Under this name Richard Volkmann (Virchow's *Archiv für pathol. Anatomie,* 1870, L., pp. 142–144) describes five cases of a peculiar chronic inflammation of the lower lip.

Symptoms.—Swelling of the lower lip gradually ensued without being especially painful and the lip became hard and tense, giving the face an unpleasant, idiotic expression. The mobility of the lip was very much impaired and in one case almost lost. The swelling involved the entire width and breadth of the lower lip to its union with the chin. In one instance the upper lip was also affected. The surrounding cutaneous integuments were somewhat erythematous in appearance. Upon close examination the mucous glands in all cases were found to be swollen to the size of a hemp seed and even larger, and were very numerous throughout the mucous membrane. When the lip was everted the follicular openings were seen to be much dilated and in some instances admitted a fine sound. On pressure, which gave rise to only moderate pain, an opaque mucous or muco-purulent discharge appeared, giving to the lip, which had been previously dried carefully, the appearance of being covered with small dew drops. In three cases abscesses occurred which originated in the glands or in the surrounding peri-acinous connective tissue. Furuncles formed in the fleshy part of the lip, which became inflamed without being especially painful, and at times the skin, but more frequently the mucous membrane, was perforated with small openings, and showed very marked tendency to fistulæ and secreted a muco-purulent discharge for weeks and months. In one case there existed simultaneously on the inside of the lower lip twelve to fifteen such openings which admitted a larger sound with ease and led to irregular fistulous passages extending through the substance of the lip. True ulceration did not occur in these openings, in any case, and no evidence of syphilitic ulcers or plaques could be demonstrated on the lip or on the mucosa of the mouth and pharynx. Two of the cases, although subjected to energetic treatment for some time with potassium iodide and local applications of silver nitrate, the point being introduced into the follicles under anæsthesia, and applications of lead water, showed but very little improvement. The remaining three cases were cured in four to eight weeks; potassium iodide, gargles of potassium chlorate, and mild cauterization being employed. All of the patients were adults. Three had previously been syphilitic shortly before the attack, and in one of these a fading syphilitic eruption on the palm was still present; with the exception of a few slightly enlarged lymphatics no local evidence of syphilis could be detected. Two patients were in perfect health and denied all history of syphilis. The course of the disease in all five cases was very similar, although differing in severity. It is quite certain that catarrhal inflammation of the labial glands existed in all these cases, accompanied by suppuration in places; actual suppuration occurred partly in the gland and partly in the peri-acinous connective tissue, hence Volkmann proposes to call the affection cheilitis glandularis or myxadenitis labialis. He is undecided as to the rôle syphilis plays in this disease; he is, however, inclined to think that it does not exert a direct influence. It is more probable that the etiological factor is to be sought for solely in the catarrhal condition of the mouth and pharynx, which always existed simultaneously, and probably spread by means of the secretion of the oral cavity through the outlets of the labial glands to the acinous bodies.

Emmanuel J. Stout.

CHELOID. See *Keloid.*

CHEQUEN.—Chekan. The leaves of *Eugenia Chequen* Molino (fam. *Myrtaceæ*). A large and beautiful white-flowered shrub of Chili and Bolivia, closely resembling the common European myrtle. The leafy twigs were originally used, but in this form by far the greater portion is inert woody fibre. The leaves average about half an inch or more in length, frequently with an obscure tooth on one side, thick, coriaceous, bright green, smooth and punctate, and aromatic in taste and odor. They contain four or five per cent. of tannin and two or three of volatile oil, the latter consisting chiefly of pinene, with some cineol. Chequen belongs, therefore, to the Eucalyptus series of aromatic drugs, its action being specially upon the respiratory mucous membrane, through which the oil is largely excreted. Its use is as a tonic expectorant, particularly in catarrhal conditions. It is commonly given in the form of the fluid extract, in doses of 4 to 8 c.c. (fl. ʒ i.–ij.). *Henry H. Rusby.*

CHERRY, WILD.—*Prunus Virginiana.* "The bark of *Prunus serotina* Ehrhart, collected in autumn" (U. S. P.). The bark of *Prunus Virginiana* L. should not be collected. It is the choke-cherry and is mostly only a shrub. This contradiction will probably be corrected in the next edition of the Pharmacopœia by dropping the word "Virginiana" from the title.

P. serotina is a large, graceful tree, with spreading, slender branches covered with red or purplish, smooth, shining bark; that of the trunk, however, is dark and exfoliating. Its wood is the valuable cherry, so extensively used for house-finishing and cabinet work. In general aspect it resembles the domestic cherry trees, but is much larger and has a rounder and more spreading top. The flowers are small (less than 1 cm. across), and borne in long, slender, rather erect, terminal racemes. Calyx cup-shaped, five-toothed. Corolla, of five-reflexed, broadly obovate white petals. Stamens, twenty or so perigynous. Ovary, simple, one-celled, two-ovuled. Fruit, a round, black, bitterish-sweet drupe, nearly 1 cm. in diameter. Stone, one-seeded.

The wild cherry tree grows in nearly all parts of the United States and Canada. In the Middle States, and in some of the Western ones, it is very abundant and large; in the extreme South it is less common, and in New England, although common, it does not attain its maximum size.

Wild cherry has been recognized by each edition of the Pharmacopœia, from the first, in 1820, to the present. Although occasionally employed in Europe, it is essentially a local drug.

The bark should be collected in the autumn, when its hydrocyanic odor and taste are the most perceptible, and that of the root, moreover, is said to be preferable to that of aërial portions; but it is an abundant and cheap drug, largely called for in domestic and other informal medicine, and apparently indiscriminately gathered. Much of it is nearly devoid of its proper odor. The Pharmacopœia description is as follows: "In curved pieces of irregular fragments, one-twelfth of an inch (2 mm.) or more thick, outer surface greenish brown, or yellowish brown, smooth, and somewhat glossy, marked with transverse scars. If collected from old wood and deprived of the corky layer, the outer surface is nut-brown and uneven; inner surface somewhat striate or fissured. Upon maceration in water it develops a distinct bitter-almond odor; its taste is astringent, aromatic, and bitter. The bark of the small branches is to be rejected." The spurious bark of the choke-cherry is much thinner and tougher, consisting largely of bast fibres, which are lacking in the genuine.

Wild-cherry bark contains substances analogous to the *emulsin* and *amygdalin* of bitter almonds. Upon being macerated in water and subjected to distillation it yields *hydrocyanic acid*, and a *volatile oil* having the properties of that of almonds. It also contains *tannic acid.*

Wild cherry is used as a sedative bitter tonic and a sedative expectorant; the sedative property due to its hydrocyanic acid, the bitter probably to its amygdalin only. It is somewhat astringent.

The above qualities express its entire value as at present understood. As a substitute for quinine it is entirely obsolete. Dose from 2 to 4 gm. (ʒ ss. ad i.). The fluid extract (*Extractum Pruni Virginianæ,* strength $\frac{1}{1}$) and the infusion (*Infusum Pruni Virginianæ,* strength $\frac{4}{100}$) are official, and represent it well. The syrup (*Syrupus Pruni Virginianæ,* U. S. P., 15 per cent.) is frequently used as a basis for cough mixtures; its taste is rather pleasant.

Allied Plants.—See *Almonds, Bitter and Sweet.*

Allied Drugs.—Cherry-laurel leaves, Peach seeds, and also Almonds and Hydrocyanic Acid.

W. P. Bolles.

CHEST, DEFORMITIES OF THE.—The chest is a box or cage enclosing and protecting the heart, lungs, and great vessels; but it is also an organ, which by its rhythmical expansion and contraction plays an important part in the respiratory act. It consists of the thoracic skeleton and of the soft parts covering it; but the position of the clavicles, scapulæ, and shoulders is so closely related to the shape and development of the chest as to require some discussion in this article.

The size, shape, and mobility of the chest vary with the race, age, sex, development, occupation, and idiosyncrasies of the individual, and it is as difficult critically to define its normal limits as it is those of the nose, ear, or any other organ or part. It is often impossible to say when normality becomes peculiarity, or peculiarity deformity.

According to Vierordt,[1] one expects to find in a well-constructed thorax, bilateral symmetry, slightly marked supraclavicular depressions, and a barely recognizable prominence at the junction of the manubrium and corpus sterni. The true ribs should so leave the sternum that there is increasing obliquity from above downward, making the angle between their free borders almost a right angle. The thorax should be well developed, and the scapulæ should lie flat upon the back; only the lower intercostal spaces should be visible. The dimensions of the chest should be proportionate to the size and development of the body, and in adult life its transverse diameter should exceed its antero-posterior in the ratio of three to two or less. Vierordt's Tabellen[2] give various chest measurements according to the most reliable observations. The mean value of chest play, or the difference in chest circumference between inspiration and expiration, is thus given as three or four inches. According to Lee,[3] the average expansion of eight hundred United States recruits was three and four-fifths inches.

Departures from the typical standard are very frequent, and may be quite marked in perfectly healthy persons. The two sides are rarely perfectly symmetrical; indeed, Vierordt himself says in another place that in right-handed people the right semicircumference of the chest is the larger by .5 to 2 cm.; in the left-handed, on the contrary, the left semicircumference of the chest is equal to or but slightly greater than the right. The chest may be small above and wide below; the angle of Louis may be more than usually prominent, and the epigastric angle exceptionally acute. The supraclavicular fossæ may be marked, without disease; but if they are unequal, apical tuberculosis may be suspected. Certain ribs, as the second, third, and fourth, may project in front, or the lower ribs may be depressed. All these peculiarities are more or less atypical without being exactly abnormal.

The broad chest of man with the square shoulders, and scapulæ placed posteriorly, correlated with the upright posture and pendant, but freely mobile and active arms, is one of the most characteristic and striking peculiarities of the human skeleton. According to Hutchinson,[4] this position of the scapulæ is a very important factor in the development of respiratory power. Human respiration is, or should be, bellows-like, the fixed flap being the spine and posterior chest wall, rather than piston-like, as it often is in cramped or rigid chests.

In the human embryo at the fourth month the quadrupedal or deep chest, with the antero-posterior diameter exceeding the transverse, still persists; at birth these diameters are nearly equal. The infant is round-chested and round-bellied, and only after three or four years of age do the chest and abdomen begin to assume the more flattened shape characteristic of adult life. In adult man the proportions of the chest are the reverse of those in the quadruped, the transverse exceeding the antero-posterior diameter in the ratio of three to two or less. Of the quadrupeds only certain monkeys, moles, and bats, all animals possessing great power and freedom of motion in the anterior extremities, have broad chests. The evolution of the human chest may be arrested before it is complete, either from congenital defect in growth or vigor or from faulty habits in childhood; we then get a long, rounded chest, a degenerate or rudimentary type, and one often associated with other defects, as will be pointed out in the sections on the phthisical chest and on round back.

Chest deformities may be divided for convenience of discussion into four groups:[5] the congenital; those due to static conditions, whether pathological or not; those due to external constriction or pressure; and those due to conditions of the internal organs. Deformities of the chest due to violence, to new growths, to local disease, or to double or non-viable monstrosities, are beyond the scope of this article.

I. Congenital Deformities.

The individual bones of the chest may be imperfect or wanting, fissured, misshapen, or augmented, and the thoracic skeleton may be deformed as a whole.

Spine.—The thoracic spine, like the cervical and lumbar, may contain too many or too few vertebræ. Dwight[6] states that since he has been looking for such anomalies, he has found them with surprising frequency. The commonest anomaly of number in the dorsal region is to have eleven or thirteen vertebræ present. Noble Smith[7] quotes a case in which four and one-half thoracic vertebræ were absent, namely, the right half of the third, the fifth, the sixth, the eighth, and the ninth. There were only two cervical vertebræ present in this case. Wedge-shaped half vertebræ on one side or the other, as in the above case, are not extremely rare; or a vertebral body may be made up of two unfused halves. The arches may be incomplete—spina bifida,—a condition which may extend to a great part or the whole of the spine, and is then called rhachischisis, with which, as with ordinary spina bifida, protrusion of a sac and various anomalies of the soft parts frequently occur. In these cases various abnormal and often extreme bendings and curves of the spine and accompanying chest deformities are often seen. The best recent article on rhachischisis is that by Thorndike.[8]

It is well for bone specialists to remember, and probably for others to forget, the possibility of anomalies in number when counting vertebræ in the living subject; also that one or more spinous processes may be bifid, or project to one side or posteriorly without pathological significance.

Sternum.—According to Dwight,[6] the sternum is about 9.5 per cent. of the total height for men and about nine per cent. for women. It may be entirely or partially absent, or more or less fissured longitudinally or perforated. These defects, like the unclosed arches of a spina bifida, are due to the failure of the primitive layers to unite in the median line. When large the gap is covered by a membrane; when small it may be entirely unnoticed during life. Holes, fissures, and defects are more common and of greater extent toward the upper part of the sternum. The xiphoid is often deflected, split, or perforated.

Ribs.—Supernumerary ribs may occur, especially in the lower cervical and upper lumbar regions. Cervical ribs on one or both sides may sometimes be palpated at the root of the neck during life, and may cause trouble by pressure on the brachial plexus and require removal. In these cases the pleural sac may rise abnormally high, and has been opened (Planet[9]). Ribs may also be absent or rudimentary. Hurtlet[10] reports five cases of rudimentary first ribs in English, and Helm[11] sixteen cases in general surgical literature. Cases occasionally occur in which several ribs on one side with their costal cartilages are imperfectly developed and fail to meet and unite with the sternum, or in the case of the lower ribs with the cartilage above, by varying intervals. They may end near the sternum or free border, below the axilla, or farther back, leaving a depression or furrow of greater or less extent to one side of the sternum, or in the lateral chest wall, covered only with skin and membrane, which may rise and fall with respiration, pulsate with the heart beats, and through which the underlying organs may be palpated. Through this unprotected area the lung may protrude, or if in the precordial region an ectopia cardis may take place. When such a tendency exists the gap should be protected by a celluloid, hard-rubber, or metal plate, and pulmonary hernias have been known to recede under such treatment, or to disappear spontaneously. These defects of the skeleton of the chest wall are due to an arrest of growth of fœtal structures, which fail to join by a larger or smaller interval.

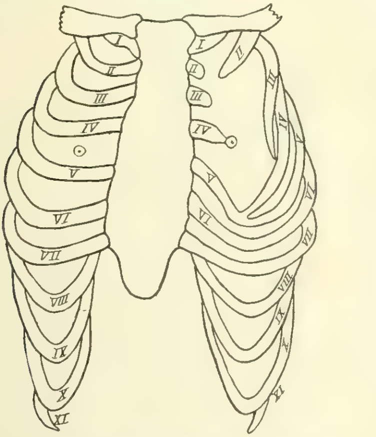

FIG. 1247.—Osborne's Case of Defect of Ribs. (From Haynes.)

The following cases are cited as examples of this deformity:

Abercrombie's[12] case was a boy of two months, with absence of the second and third costal cartilages, left side; the corresponding ribs ended free, leaving a small unprotected space. The fourth rib lay near its cartilage, but was not joined to it. There was a notch on the left side of the sternum near the third interspace.

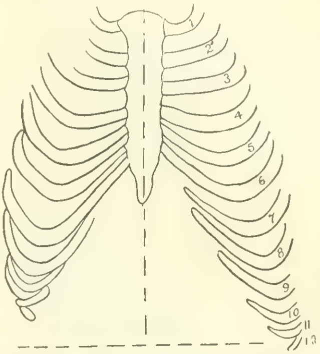

FIG. 1248. Haynes' Case of Defect of Lower Ribs on the Left Side. (From Haynes.)

Bennett's[13] case was that of a man who died suddenly after an injury. The autopsy disclosed a defective third rib, right side, which failed to reach its cartilage by a considerable interval. This case and another reported by Bennett emphasize the danger of mistaking certain congenital chest deformities for the effect of injury, recent or remote.

Osborne's[14] case was a boy with a triangular depression on the left side of the chest due to defective development of the second, third, and fourth ribs, which were separated from their cartilages by a considerable interval. The extremity of the fourth rib was joined to the fifth costo-cartilaginous articulation.

In Townsend's[15] case the ribs of the left side, except the first two, were represented by short rudimentary processes.

Lallemand's[16] case was a man with a depression as big as a fist on the left side of the chest, due to a deficiency of the third, fourth, and fifth ribs.

Harold's[17] case was a backward boy of seventeen years, whose costal cartilages in the left side below the fifth rib were missing; at this level the left half of the sternum and xiphoid were deficient, and the pericardium was protected only by soft parts.

Homer Gage[18] reported a case of congenital absence of the sixth, seventh, eighth, ninth, and tenth ribs, left side, in a girl of seventeen years. There was severe lateral curvature, convexity to the right, with severe deformity of the chest, and a protrusion in the unprotected area, supposed to be due to a hernia of the stomach. The heart was displaced to the right, though the viscera were not transposed.

In Hayne's[19] case the cartilage of the seventh rib, left side, ended three-fourths of an inch from the sternum, and the seventh, eighth, and ninth cartilages were not joined, but ended free.

Sometimes the costal defect is accompanied by total or partial absence of the greater and smaller pectoral muscles of the same side, as in the case reported by Levy,[20] in which the third and fourth ribs of the right side ended below the axilla, leaving a marked depression. There was a well-marked lateral curvature with convexity toward the right.

Schlesinger[21] has shown that congenital absence of the pectoral muscles is frequently associated with defects of ribs or other thoracic anomalies, and cites the case of a man of twenty-two years who had in addition to a defect of the third, fourth, and fifth ribs, and of the costal portion of the pectoral, a congenital elevation of the shoulder—Sprengel's disease—all on the left side. It would seem that defects in the costal apparatus are more common in males and on the left side, that they are frequently associated with other thoracic anomalies, and that they sometimes occur in individuals otherwise or generally defective.

Other thoracic deformities sometimes accompany congenital malformations of the heart; there may be in such cases a projection or gibbosity of the front of the thorax above the xiphoid, "thorax en proue," or "thorax en carène," or the thorax may be prominent in front with flattened sides (see Charrin and Le Noir[22]).

Occasionally there is a fusion of ribs, usually the first two, which are then sometimes called a bicipital rib. Other ribs may be fused at one or more points (*Deutsche Chirurgie*[illegible]).

Stiller's Costal Stigma — Costa Fluctuans. — Stiller maintains that the majority of cases of enteroptosis begin in youth and are associated with abnormally movable tenth ribs. This mobility may approximate that of the two lowest pairs of ribs, and is due to a congenital and possibly inherited defect in the cartilage, which joins the tenth ribs with the cartilage above. He claims that enteroptosis and nervous dyspepsia are identical, and that children exhibiting the costal sign will always go on to have enteroptosis, atony of the stomach, constipation, and nervous dyspepsia or dyspeptic neurasthenia. He finds these conditions nearly as common in men as in women, and concludes that tight lacing and pregnancy have but little to do with enteroptosis.

Absence of the Pectoral Muscles.—This deformity occurs more frequently on the right side, and may involve both the large and small pectorals, but the pectoralis minor and the clavicular portion of the former often escape. The affected side of the chest has a flattened or excavated appearance, but the patient has full use of the arm and suffers no inconvenience, and may even be a good soldier or gymnast. An infant six weeks old with absence of the costal portion of the left pectoral was exhibited by the writer to the Orthopedic Section of the New York Academy of Medicine in January, 1898, and by a singular coincidence a boy of sixteen years with the same deformity on the right side was shown at the same meeting by Dr. Royal Whitman. In these cases there are usually certain anomalies of the neighboring soft parts such as deficient subcutaneous tissue, scanty hair over the affected area and in the axilla, imperfectly developed mammilla, breast, and anterior axillary border of the affected side. In certain cases defects of ribs and anomalies of the scapula may exist, as in a case reported by the writer,[25] and one described by Schlesinger,[21] who has collected one hundred cases of pectoral defect from medical literature, and who states that in about one-quarter of the cases the pectoralis minor is also absent; in one-tenth of the cases there is considerable anomaly of the thoracic skeleton, and in one case in twenty or twenty-five there is pulmonary hernia or displacement of the heart.

Funnel Chest, Funnel Breast, Trichterbrust, Thorax en Entonnoir.—This deformity is one of the most interesting of the congenital chest deformities, and has attracted considerable attention since Ebstein's[26] paper appeared in 1882, though the condition had been previously described. Stedman[27] gives the earlier references.

In these cases there is a considerable depression involving the lower portion of the sternum, and the adjacent cartilages and ribs. This depression may be large enough to contain a man's fist, and is usually congenital, but its etiology is obscure. Some authors suppose it to be due to a defect in development, others to the pressure of the fœtal chin or heels. Certain authors regard it as a stigma of degeneration, as it has been found in the insane, epileptic, and neuropathic; others have observed it in robust and well-developed individuals. It occurs more frequently in men; out of thirty cases twenty-three were males.

Arneill[28] reports six cases, of which five occurred in one family. These were a student, his brother, father, and two paternal uncles. This patient was twenty-five years old, six feet tall, and weighed one hundred and seventy-four pounds; he was well developed and in excellent health. In his case the antero-posterior diameter of the thorax was, at the right nipple 17.5 cm., at the left 16.8, and at the depression in the median line 11.4. The greatest depth of the depression was 6.5 cm. In the brother the depth was 4.7, and in the father 3.75. There was one sister who was free from defect. Of Klemperer's[29] three cases two were brothers. The writer has recently reported the cases of a mother and daughter.

A number of cases of acquired funnel chest have been reported. The deformity may be acquired by traction from within, from adhesions, or bronchiectasis, or by pressure from without, as in certain occupations. An excellent account of this and other chest deformities may be found in an article by Marie.[30] As already noted, there is little or no interference with function, and some individuals are able to take violent exercise, as respiratory capacity does not seem to be diminished. Ebstein[26] has described some cardiac displacement upward and to the left.

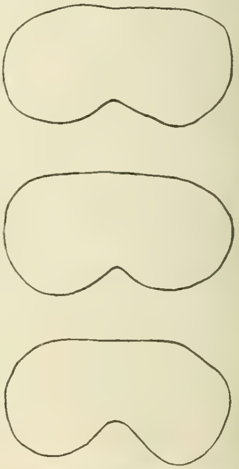

FIG. 1249. — Funnel Chest. (Arneill's cases.)

Thorax en Gouttière.—Somewhat similar to funnel chest is the "thorax en gouttière" of Féré and Schmidt,[31] where the sternum forms the bottom of a longitudinal trough or gutter whose sides are the incurved costal cartilages. These authors claim that ten per cent. of epileptics show this deformity.

Clavicles.—The clavicles may be wholly or partly absent on one or both sides. In partial absence it is usually the outer extremity which is wanting. The shoulders drop forward and inward, and may even be made to meet in front, but there is surprisingly little interference with function. The writer's clavicle splint[32] may be used to keep the shoulders in position, acting on the principle of artificial clavicles.

Congenital Elevation of the Scapula—Sprengel's Disease.—This condition was first described by Sprengel in 1891, and is not yet thoroughly understood. An excellent discussion of the subject may be found in the recent paper by Nové-Josserand and Brisson,[34] who report twenty cases in literature and their own observation of a girl of nine years with the right scapula 3 cm. higher than the left. Besides being elevated the scapula was rotated so that the inferior angle was nearer the spine, and the spine of the scapula pointed downward and outward. The upper border of the scapula pointed upward into the neck, producing a noticeable deformity. The right scapula was somewhat smaller than the left, but the clavicles were equal. The movements of the shoulder joint were free, but the arm could not be raised as high as on the opposite side. The muscles responded normally to electric stimulation. The above description is typical, and applies to most cases. In about half the cases there is a slight scoliosis, of which the convexity may be from or toward the affected side.

In some cases there is facial asymmetry, the side of the elevated scapula being the less developed. There is little disability, sometimes none, and when treatment is required remedial gymnastics are sufficient. The writer[25] has reported a case of small scapula with absent pectoral muscle on the right side. This case seems to belong in this group, though the elevation of the shoulder was slight.

A peculiar form of congenital high shoulder, in which the scapula was joined to the spine of the seventh cervical vertebra by a bony process, has recently been described by Wilson and Hugh.[35]

Congenital Scoliosis.—This deformity involves more or less all the bones of the thorax. The cases in which lateral curvature is congenital are rather rare, though Marie[30] thinks that many cases of lateral curvature which develop in childhood may be due to congenital defects of the thorax or spine, which remain latent or without visible effect for years, but finally produce a visible curvature. He includes such cases under the term "déformations thoraciques congénitales tardives." In a recent study Hirschberger[36] attributes a certain number of cases of congenital lateral curvature with defects of the spinal column to intra-uterine pressure, with scanty amniotic fluid. Another group is associated with other anomalies, showing a widespread developmental fault. A few cases only are due to paralysis.

The chest deformities associated with lateral curvature will be more fully described in a subsequent section.

II. Acquired Deformities.

(*a*) *Chest Deformities Due to Static Conditions.*—This group comprises the chest deformities due to the various forms of lateral curvature of the spine, weak and round back, to spondylitis, and in part to certain constitutional diseases affecting the bones, such as acromegaly, osteitis deformans, and spondylitis deformans.

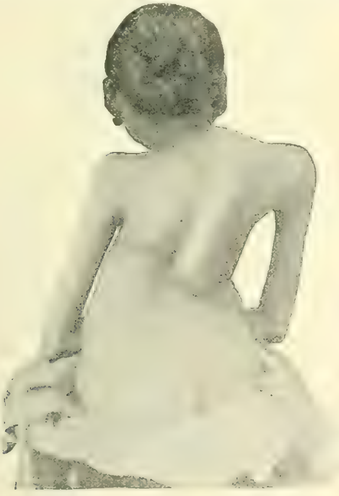

FIG. 1250 Chest Deformity in Severe Scoliosis.

Lateral curvature of the spine, or scoliosis, is the name of a striking symptom, whose causation varies widely in different cases, and in many is exceedingly obscure. The list of diseases and conditions with which lateral curvature is more or less frequently associated is a long one, but in all the efficient cause is an asymmetrical or unilateral weakening of the skeleton or muscles, often due to a one-sided incidence of stress, as an habitual faulty or one-sided posture, loss of an arm, short leg, congenital defects of spine or chest, torticollis, Sprengel's disease, sacro-iliac disease; in other cases to asymmetrical softening, hardening, or distortion of certain parts of the skeleton as in rickets, cretinism, achondroplasia, acromegaly, diffuse hyperostosis (leontiasis), osteomalacia, rheumatism, spinal osteo-arthritis, osteitis deformans (Paget's disease), pulmonary osteo-arthropathy, and often tuberculous spondylitis; also in certain nervous and paralytic disorders which affect the spinal and trunk muscles in an asymmetrical manner, such as poliomyelitis, sciatica, Friedreich's ataxia, syringomyelia, hysteria, athetosis, paralysis of certain spinal muscles, and some of the chronic muscular atrophies and dystrophies. The commonest and most important class, however, is that in which the lateral curvature is attributed to muscular weakness and habitual faulty postures, but in which no very obvious predisposing cause is evident and about the causation of which very little is really known.

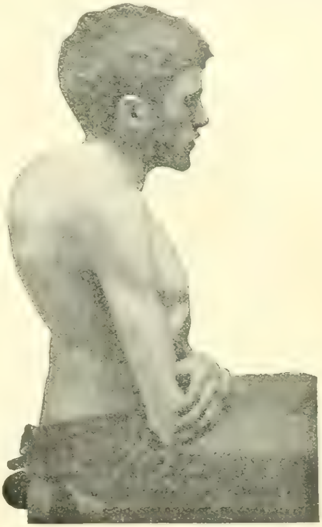

FIG. 1251. Antero-Posterior Chest Deformity in Severe Scoliosis. The posterior boss is on the right side only.

The distortion of the spinal column is probably the most important but by no means the only element in the deformity. The entire thorax becomes by degrees warped and twisted, and while the different varieties of lateral curvature vary in their characteristics, and the ordinary or postural deformity in the degree of distortion finally reached, it is not too much to say that the severer grades are among the most distressing, and, unfortunately, the most common of severe chest deformities. In many cases the distortion or debility affects not only the trunk, but the pelvis, head, and extremities.

The spine usually has a dorsal and a lumbar curve in opposite directions. The convexity of the dorsal curve is to the right in a large majority of cases. The spine is also twisted on or near its axis in the same direction in which it curves, owing to its lying free from support in the thoracic and abdominal cavities: the line of the vertebral bodies thus comes to be much more curved than the line of the spinous processes—in other words, the deformity is much severer and more complicated than it appears to be from external inspection. After the deformity has lasted some years, the bodies of the vertebræ become wedge-shaped and twisted, the intervertebral discs compressed, and the deformity becomes fixed. The development of this spinal distortion has a profound effect upon the shape of the chest, which becomes shortened in height, reduced in most of its measurements, and is rendered stiffer and less flexible. The ribs on the side of the dorsal convexity become more bent at their angles, making a projection under the corresponding scapula; this projection is sometimes very prominent, producing a large posterior bosse. The ribs on this side are more separated at the sides and in front and become broader, but are crowded together behind, where they may form false articulations with the spine and with each other. On the concave side the ribs become straighter and narrower, and there is a flattening or depression in and below the scapular region. The scapula is usually lower and less prominent on the side of the dorsal concavity, higher and more prominent with projecting inferior angle on the convex side. With a right dorsal convex curve, the left side of the thorax is prominent in front, and the left breast and left free margin of the ribs protrude; the diagonal from right back to left front is much longer than normal, and exceeds all other horizontal measurements; the opposite diagonal is much shortened, and a horizontal transverse section of the chest shows an irregular ellipsoid, lying in the direction of the long diagonal. Both lungs are cramped, the right the most, breathing capacity is much diminished, the heart is displaced to the left, and the abdominal and pelvic organs are crowded. The direction of the sternum is changed, and the whole thorax and trunk are strangely shortened and twisted. It is strange that chronic pulmonary disease is so seldom met with in these severe cases of lateral curvature. They are, however, not strong, and do suffer from their deficient respiration and imperfect circulation in a delicate organization, poor blood, and defective nutrition. Satterthwaite[37] has specially studied the displacements of the heart due to lateral curvature, and Faber[38] the respiratory difficulties.

The foregoing description may serve to indicate the principal characteristics of the chest deformities accompanying the commonest form of lateral curvature. In the lateral curvature due to morbid processes affecting the osseous system, the bones of the chest will present, besides the deformities of lateral curvature, those due to the special morbid process, such as softening, hypertrophy, or local distortion. In paralytic lateral curvature there is less rigidity, and there may even be increased flexibility, and paralysis of certain muscle groups will be found.

For the symptomatology and treatment of lateral curvature, and for its effects on other parts of the body, the reader is referred to other sections of this work.

Chest Deformities Associated with Paralytic Affections.—The commonest is lateral curvature and its accompanying thoracic distortions as mentioned in the preceding paragraph, and the commonest variety of paralytic lateral curvature is that associated with a certain number of the severe cases of acute poliomyelitis, in which the trunk or spinal muscles are asymmetrically involved.

In the progressive myopathies of the scapulo-humeral type, and of the facio-scapulo-humeral type, and in pseudo-hypertrophic paralysis, there often occurs, according to Marie,[39] a flattening of the upper part of the thorax. Atrophy of the pectorals in connection with this deformity causes the upper part of the chest in front to have an excavated aspect. In some cases this depression is found in the lower part of the chest giving an appearance similar to funnel chest, and these deformities may be combined with scoliosis. Certain of these atrophic affections produce a wasp figure, the obliquity of the ribs being increased, and the chest being straight at the sides and cylindrical, with a marked depression or constriction between the lower ribs and the thoracic crests, owing to atrophy of the waist muscles.

Round back, kyphosis, round shoulders, stoop shoulders, are faulty postures or deformities, in which the head, shoulders, and upper chest fall or sag forward, from improper poise and muscular weakness. The result is a rounded back, and consequent changes in the shape of the chest, position of the head and shoulders, and, indeed, a general fault of attitude, a de-energized position in which the principal stress is shifted from the muscles to the ligaments. There has been considerable confusion in the nomenclature and in the description of this affection, or rather symptom. Round shoulders is a term in common use, but is unsatisfactory since the faulty position of the shoulders is a secondary symptom, largely due to the shape of the back and chest, for which reason the term round back is preferred by the writer, though this term also fails to indicate the general disturbance of poise which is usually present. The term kyphosis is unfortunate, since it is also used to designate the deformity due to Pott's disease of the spine, from which it is exceedingly important to distinguish it.

Round back or weak back, then, is that position of relaxation into which the body falls when the upper trunk is no longer held up by weakened spinal muscles. Excluding the angular projection of Pott's disease, which becomes rounded only in the latest stages, the affection may be divided into several varieties, namely, those due to: (1) Imperfect development of the chest; (2) congenital or acquired weakness—convalescence; (3) old age; (4) paralytic affections; (5) certain diseases which affect bone and general nutrition, such as rickets, scurvy, cretinism, spondylitis deformans, osteitis deformans (Paget's disease), acromegaly, pulmonary osteo-arthropathy. The list is very similar to that given for scoliosis, but whereas in that case the bony or muscular support was weakened on one side, in this the weakening is approximately symmetrical.

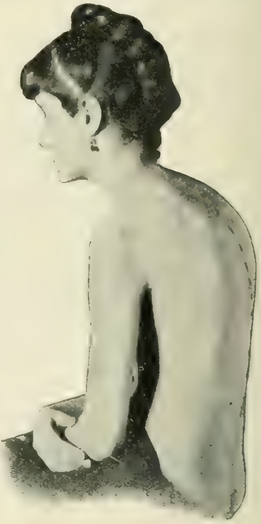

FIG. 1252.—Severe Round Back. (Original.)

Most of these kyphotic conditions have in common the forward sagging of the spine for lack of bony or muscular support or both. The head and upper chest fall forward, the spine becomes more or less rounded, the chest becomes compressed at its upper part, but may become narrower rather than flatter as a whole; the ribs drop downward, the shoulders and scapulæ downward and forward, their inner borders receding from the spine and their inferior angles becoming more prominent. The position of the pelvis is changed, the feet are weak or flat and everted, and there is a tendency to knock-knee. The chest is usually less flexible than normal, respiratory capacity and power are diminished; there is often a transverse furrow at the upper border of the abdomen. The attitude is that of fatigue, weakness, debility, relaxation. It is doubtless an attitude which may be produced or intensified by habitual faulty positions, such as those assumed for many hours daily by school-children or clerks at their desks. This factor, however, must usually be associated with fault of structure or inherited or acquired vice of nutrition, muscle tone, or skeletal resistance, in order to be effective. It is to be noted that the non-pathological form of round back often affects children as early as the fourth or fifth year, and that, as already remarked, it is rather a general than a local affection. Weak and pronated feet, week eyes, and slight degrees of lateral curvature often accompany it. These children are often physically delicate and mentally unstable. They may inherit an imperfect physique, or their life is so precocious or intense, as to interfere with ample and symmetrical development. In other words, a good many of these children are degenerates or bordering on degeneracy, and present the rounded back and drooping shoulders as striking symptoms, but usually show other unmistakable signs of imperfect development. The writer believes that in a certain proportion of these round-backed children, the evolution of the chest has been retarded or arrested at a certain stage either from inherited tendency or from causes acting in early childhood, irrespective of faulty attitudes, and that this rudimentary chest stands in close relation with the pre-tuberculous type of chest described by Hutchinson. It is probable that in a certain class of cases the faulty attitude is in large measure dependent on the long, narrow, and deep chest, which favors drooping shoulders and abducted scapulæ, and to the instinctive desire of the delicate, under-nourished, and over-stimulated child to shift the strain of bodily weight from the tired muscles to the insensitive ligaments.

It follows that purely local treatment rarely fulfils the indications, and that management with a view to general development and a proper regulation of the life is of primary importance. The chest should be amply developed in early years by a free, open-air life, with plenty of tree and hill climbing, romping, rambling, swimming, running, and ball-throwing, sports that involve well-distributed and vigorous exercise, and especially develop arm action and respiratory power.

The habits should be regulated and over-stimulation avoided. When the chest deformity is pronounced, special corrective and gymnastic exercises are of great benefit. Remembering that the faulty attitude is general, it is often necessary to begin by strengthening, placing, and shoeing the feet, in order to secure a correct pose. Thus the pupil should be drilled in the proper poise of the body, chest forward and up, abdomen and hips back, weight on balls of feet. After these matters have been attended to, breathing and corrective exercises may be successfully applied to the chest. Supporting apparatus is seldom, and shoulder straps are never, required. The senseless admonition to throw the shoulders back without attention to these preliminaries would be productive of much harm if it were not almost invariably disregarded.

The round back of certain occupations and of convalescence are varieties of the round back of weakness. The round back of old age is accompanied by changes of form in the chest similar to those described. It is due to the gradually increasing muscular weakness and ligamentous rigidity due to advancing age. The spinal muscles, whose tonus is diminished, no longer suffice to hold the spine erect and the chest free. The drooping spine compresses the intervertebral discs anteriorly; their elasticity is impaired, and the false attitude finally becomes fixed. The only efficient prophylactic is an active and well-distributed muscular life in youth and manhood with the avoidance of debilitating influences.

In round back due to paralytic disorders the spine is often extremely flexible, though respiratory power is diminished from muscular weakness. The chest often remains collapsed, and the breathing may be abdominal. The management is usually that of the disorder upon which the round back depends. Special exercises and supports are sometimes of service, and the writer has found the prone position on an inclined padded board or mattress to have an excellent influence in stimulating the spinal erector muscles to action, and in correcting the deformity.

The round back of paralysis agitans is similar to that of old age.

The round back or so-called kyphosis of rickets, infantile scurvy, cretinism, and marasmus usually comes on in infancy before the child is able to walk, and consequently before the evolution of the normal antero-posterior curves of the spine. The sitting posture probably has much to do with its production, and the projection is of a different character from that described in the first part of this section. It is rounded and situated in the middle or lower part of the back, though it may involve nearly the whole spine, which is more or less flexible and free from muscular spasm; there is no characteristic pain. It differs in all these respects from the kyphosis of spondylitis, with which it is sometimes confounded, and which it is exceedingly important to differentiate. Mechanical support is rarely required, as the deformity usually recedes under recumbency for longer or shorter periods, together with the treatment appropriate for the dyscrasia. In the rare cases in which the deformity persists and becomes rigid after the cure of the disease, the treatment is difficult, and mechanical support may be required.

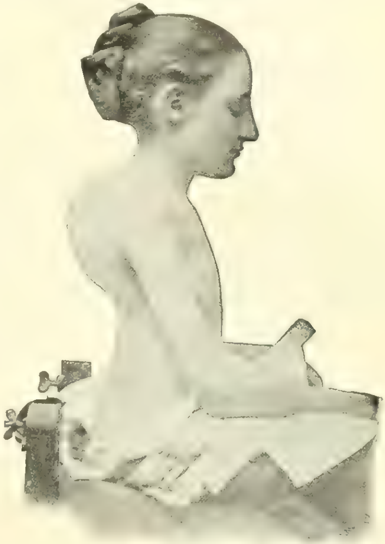

FIG. 1253.—Rounded Kyphos of Cured Pott's Disease. (Original.)

In acromegaly the dorsal spine may become rounded, and the ribs, sternum, and clavicles hypertrophied, giving a massive, deep chest. The bent back and exaggerated senile attitude may occur in osteitis deformans (Paget's disease) and in osteo-arthritis of the spine.

Angular Kyphosis.—In Pott's disease the integrity of the spinal column is destroyed by local tuberculous ulceration, and the upper section of the trunk falls forward until it finds support, giving rise to a kyphos, or hump of the back, which is at first always angular, and to various changes in the shape of the chest, especially if the disease affects the thoracic vertebræ. In disease of the upper dorsal region the upper part of the chest is flattened in front. In disease of the mid-dorsal region the ribs become more sloping, in severe cases resting on the ilium or within the pelvis; the chest becomes shortened and laterally compressed; the sternum and lower ribs become prominent, and the antero-posterior diameter of the chest is increased. The chest also becomes very rigid, and the breathing abdominal and accelerated.

The changes in the shape of the chest take place very slowly, and are only fully developed after several years. There are always rigidity and spasm of the spinal muscles during the active stage, and often restlessness or crying at night, abdominal pain, and a characteristic attitude. These points and others differentiate it from the rachitic spine already described. The treatment is that of Pott's disease, which includes attention to hygiene and nutrition, long-continued spinal support by special appliances, the avoidance of exercise, and more or less recumbency.

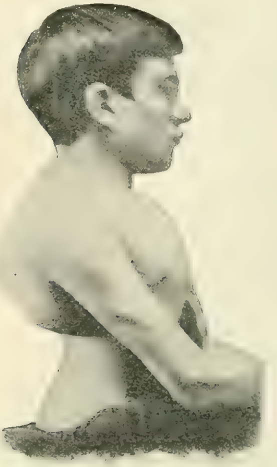

FIG. 1254.—Kyphos and Chest Deformity of Cured Pott's Disease. (Original.)

The Rachitic Chest.—Besides lateral curvature and kyphosis there are other deformities of the chest so frequently found in rickety children as to merit separate mention.

Harrison's Groove.—The greatest softening in the rachitic chest takes place in the cartilages of the lower ribs, where the chest is unprotected by the lifting action of the upper and lateral chest muscles. Just below the nipples there is nearly always a depression, which in severe cases extends upward near the costo-sternal junction or outward toward the axillary line. It has often been thought that this depression was due to the traction of the diaphragm, but it lies above the diaphragmatic attachment. The free border of the ribs is usually prominent, owing to enlarged liver and spleen and distended abdomen. These lateral depressions of the chest are in such a position that they are comfortably filled by the flexed forearms of the child, but it is improbable that the pressure of the arms has anything to do with their production. According to Stone,[39] flattening of the sides of the chest is less common than the formation of a transverse groove and occurs in about a quarter of the cases. The enlargement of the costo-chondral junctions, which forms the rachitic rosary, is often so great as to be plainly visible.

Pigeon Breast, Pigeon Chest, Chicken Breast, Keeled Chest, Pectus Carinatum.—The submammary flattening, the formation of a transverse sulcus, the flattening of the sides of the chest, and the flattening of the upper anterior chest enter into the formation of pigeon breast, which is simply the final outcome of a process of which the flattening is the first stage (Stone). In pigeon chest the sternum, and especially its lower part, is prominent, and the costal cartilages slope away abruptly at the sides. The antero-posterior diameter of the chest is increased, the lateral diminished, and the chest is much narrowed in front; it is also shorter than normal.

The reverse condition with a depression over the sternum may occur as the result of rickets. Both these deformities may be more pronounced on one side. These rickety chests are not only misshapen, but after the subsidence of the rickets they may remain unduly rigid and dwarfed.

Besides impeding respiratory movements, these rachitic chest deformities cause very little trouble, and when fully developed are practically incurable. Amelioration may sometimes be obtained by respiratory and general exercises. During the stage of development the treatment of the rickets is very important.

Similar conditions are sometimes due to obstruction of the air passages by adenoids, swollen turbinates, enlarged tonsils, polypi, or hypertrophic rhinitis. Tubby[40] relates several such cases, giving illustrations of the deformities produced. He says the proof of the dependence of the chest deformities upon the conditions named is given by their rapid improvement after the removal of the obstruction to respiration. A mild grade of these conditions is not uncommon in school-children, and is often accompanied by mouth breathing, and by inattention and apparent mental dulness, which clears up when the cause is corrected.

(*b*) *Chest Deformities Due to Lacing.*—Certain chest deformities are due to pressure from without, and of these the commonest is the constriction of the waist and lower chest by corsets among civilized women. The use of corsets, even when loosely laced, prevents the proper expansion of the lower ribs in respiration, and forces the breathing into the upper thorax. This effect has been so universal that the exaggerated upper thoracic breathing of women is usually described as a normal peculiarity of the sex, but it has been pretty well established that boys and girls breathe alike until the girls put on corsets, and that women who do not wear corsets breathe very much like men, that is, with a bellows action of the whole chest, and not with a piston action of part of it. The evil effects of this abnormal constriction are seen not only in respiration, but even more in the crowding and displacement of the viscera. The liver may be deeply indented with the marks of the compressing ribs, and the ribs themselves

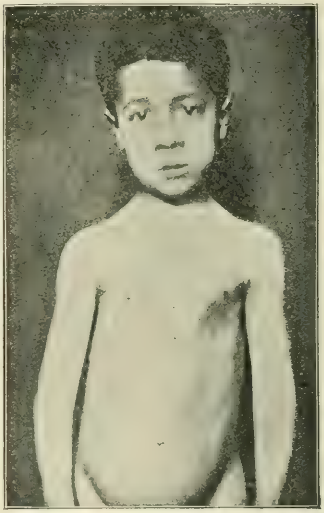

FIG. 1255.—Rachitic Chest, Showing Pigeon Breast and Harrison's Groove. (Hospital for Ruptured and Crippled.)

are often misshapen about the waist. The stomach, intestines, and pelvic organs are frequently displaced downward, with many resulting ills. The rigidity and compression of the stays weaken the waist, back, and abdominal muscles, and interfere with the natural support and normal mobility.

Cobbler's Chest.—Some occupations cause special chest deformities, such as the cobbler's chest, due to the pressure of the last against the end of the sternum, producing a depression similar to funnel chest, but lower.

Tailors who sew in a bent-over attitude often have a hollow chest.

(*c*) *Deformities Due to Changes in the Thoracic and Abdominal Contents.*—The last division of chest deformities includes those that are due to changes in the thoracic or abdominal contents.

The Inflated, Distended, or Emphysematous Thorax.—The typical chest of emphysema is large and rounded or barrel-shaped. It is, in fact, a chest which permanently retains the shape of extreme inspiration, owing to the ballooning of the enlarged and dilated lungs, or, according to Campbell,[41] to overaction of the inspiratory muscles, the antagonistic pulmonary elasticity being impaired. The ribs are strong and leave the sternum nearly at a right angle, making the thorax appear short. The sternum is prominent, especially at the angle of Louis, and the epigastric angle is large. The supraclavicular depressions are shallow or effaced; they may even be converted into elevations, if the pulmonary apices are markedly emphysematous. This is by no means always the case; they may even be deepened. The chest is immobile, and the breathing abdominal. While one may safely infer the presence of emphysema from the rigid, inflated chest, one should not call the large, deep chest of well-built and active men emphysematous, nor should one forget that in many cases of emphysema the lungs are not enlarged, and the chest fails to present the above-described characteristics.

One-sided distention of the chest, particularly in its lower part, may occur in pleuritic effusion and empyema of one side, in which conditions there may be bulging of the lower intercostal spaces. In proportion as the breathing is crippled on the affected side, there will be inflation and overaction of the well side, especially at the upper part in front. Hypertrophy of the heart, pericardial effusion, and aneurism may cause enlargement in the precordial region, and marked enlargement of the liver or spleen may cause a bulging of the ribs on the corresponding side. Chronic distention of the stomach and bowels may cause prominence of the lower ribs on both sides. Effusions and enlargements of the internal organs will affect the shape of the chest in proportion to its flexibility. These deformities are therefore most marked in children, less in adults, and least often observed in the aged. In individuals with rigid chests changes in the internal organs may produce but slight effect.

The Phthisical, Phthinoid, Alar, Paralytic, or Rudimentary Chest.—This is partly a rudimentary and partly an atrophied chest. It has usually been described as flat or flattened, but Hutchinson[42] has shown that it may be not only relatively but absolutely longer, narrower, deeper, and rounder than normal, approximating the quadrupedal type. It is apparently a chest whose evolution has been arrested at a lower stage. In the chest of phthisis the ribs are depressed, and the intercostal and supraclavicular spaces may be sunken. The epigastric angle is diminished; costal breathing is lessened on the affected side.

If chest development is arrested in childhood or adolescence, the liability to phthisis is increased, and one may infer a certain predisposition to pulmonary tuberculosis from the existence of this chest in the young. The investigations of Gabrilowitch[43] confirm these views. He found that the ratio of the circumference of the best-shaped chest to the total height was as 1 to 1.6. The ratio of the mean antero-posterior diameter to the transverse was as .70 to 1 in normal individuals, but in phthisical individuals the proportion was .73 to 1. Rothschild[44] criticises Gabrilowitch's methods and conclusions, and gives the ratio of chest depth to chest breadth as 1 to 1.8 in healthy individuals, and as 1 to 1.5 in phthisical subjects with thorax paralyticus. He gives the chest circumference as one-half the total height, and the length of the sternum as one-fifth the chest circumference in the healthy, less in thorax paralyticus. He also states that the angle of Ludovici and the angular movement of the sternum in respiration are less in phthisis (see measurements by De Giovanni[45]). The whole subject apparently requires more exact and extensive study.

During the destruction of lung tissue atrophy of the muscles of the chest takes place, and is most pronounced on the side most seriously involved, and unilateral if the disease is unilateral.

Carcasonne[46] finds that atrophy of the scapulo-thoracic muscles takes place early and independently of general emaciation; it may even precede auscultatory signs. This atrophy is not accompanied by functional changes in the muscles, nor is their electric excitability altered; it advances with the progress of the pulmonary lesion, and is of considerable diagnostic value. The analogy of this concomitant atrophy of the muscles of related areas with the primary atrophy in joint disease is evident. In the latter case, however, the tonus and mechanical and electric excitability are said to be increased.

The very great importance of an active out-of-door life, of exercise stimulating deep breathing, and of free use of the arm and shoulder muscles for the round-shouldered and alar-chested, is apparent. Swimming, running, climbing, and throwing are particularly indicated.

Unilateral shrinking of the chest occurs in phthisis of one side. The deepening of one supraclavicular fossa is an evil symptom. Over a shrunken cavity the chest may present a depressed appearance, with hollow intercostal spaces. From the atrophy already mentioned, as well as from the traction of adhesions, there may be depression of the chest wall without cavity. After pleurisy and empyema, if the lung does not expand, the affected side of the chest may become markedly shrunken, and the whole thorax deformed with a scoliosis, whose convexity is toward the well side.

Henry Ling Taylor.

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CHEST, PHYSICAL EXAMINATION OF THE.—Physical examination of the chest is accomplished by the use of the special senses of sight, hearing, and touch in the application of the methods of inspection, palpation, mensuration, percussion, and auscultation. The phenomena observed by these methods of investigation are called physical signs. To recognize and properly interpret the physical signs caused by abnormal conditions of the thoracic viscera it is essential that the observer should thoroughly understand the normal physical signs and be able to recognize them.

The physical signs obtained on examination indicate to the observer the condition of the organs examined, and from the consideration of these physical signs together with the subjective symptoms and history of the patient, the diagnosis of the disease producing the pathological changes is made. The diagnosis should never be made from the physical signs alone.

Physical Examination of the Lungs.

Topography of the Chest.—For convenience in description and for reference the surface of the chest is divided into anterior, lateral, and posterior regions by vertical and transverse lines.

Vertical Lines.—Anterior median or mid-sternal; sternal line drawn parallel to the edge of the sternum; mid-clavicular line drawn downward from the middle of the clavicle, usually passes through the nipple in men, and is, therefore, sometimes called the mammary line; parasternal line, drawn midway between the sternal and mid-clavicular lines; anterior axillary line drawn through anterior fold of axilla; mid-axillary line and posterior axillary line drawn through middle of axilla and posterior fold respectively; scapular line drawn vertically through angle of scapula when the arm hangs at the side; posterior median line.

Transverse Lines.—On the anterior surface of the chest transverse lines are drawn parallel to the lower borders of the third and sixth ribs, the latter of these lines prolonged also divides the upper from the lower axillary regions; on the posterior surface lines are drawn parallel to the second rib, through the spine of the scapula, and joining the angles of the scapulæ.

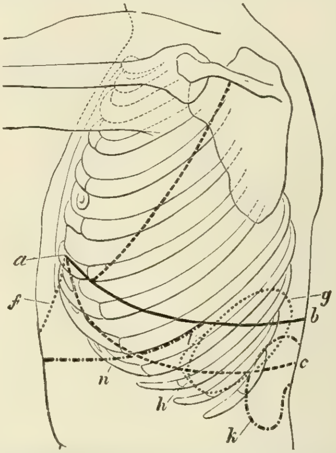

FIG. 1257.—Lateral Surface of Chest. ———, Continuous line, lower border of left lung; -------, broken line, fissure between left upper and lower lobes, lower border of pleura; ...., dotted line, spleen and liver; -·-·---, dot and dash line, stomach and kidneys; *ab*, lower edge of left lung; *ac*, lower border of pleural sac; *f*, edge of left lobe of liver; *g*, posterior, *h*, anterior end of spleen (when oval in shape); *k*, lower edge of left kidney; *n*, greater curvature of stomach. (From Sahli.)

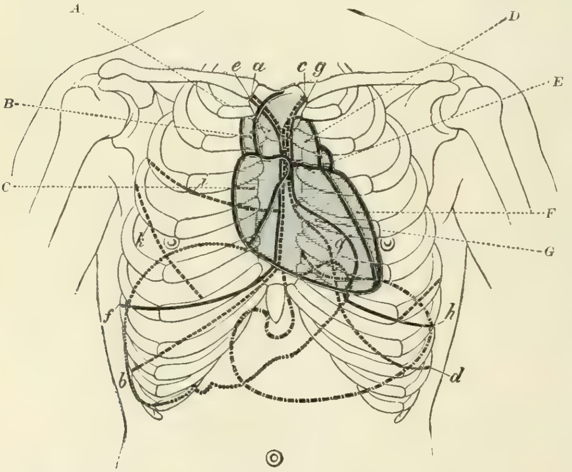

FIG. 1256.—Anterior Surface of Chest. ———, Continuous line, border of lungs; -------, broken line, fissures between lobes and line of pleura; ...., dotted line, liver; -·-·---, dot and dash line, stomach; ═══, double line, heart and great vessels. *A*, Aorta; *B*, vena cava superior; *C*, right auricle; *D*, pulmonary artery; *E*, left auricle; *F*, left ventricle; *G*, right ventricle; *ab*, border of right pleural sac; *cd*, border of left pleural sac; *ef*, edge of right lung; *gh*, edge of left lung; *i*, fissure between right upper and middle lobes; *k*, fissure between right middle and lower lobes. (From Sahli's "Lehrbuch der klinischen Untersuchungs-Methoden," etc.)

Anterior Regions.—Supraclavicular, above the clavicle; clavicular, that portion of chest covered by clavicle; infraclavicular region, from lower border of clavicle to lower border of third rib; mammary region, from lower border of third to lower border of sixth rib; inframammary region, from lower border of sixth to free border of ribs; upper sternal to lower border of third rib, and lower sternal, from lower border of third rib to ensiform cartilage.

Lateral Regions.—Axillary region to lower border of sixth rib; infra-axillary, from lower border of sixth to free margin of ribs.

Posterior Regions.—Upper scapular, from second rib to line of spine of scapula; lower scapular, from spine of scapula to angle of scapula; infrascapular, from line joining angles of scapulæ to twelfth rib; interscapular region, that portion of posterior surface which lies between the scapula and the spine.

Relation of the Borders and Fissures of the Lungs to the Surface of the Chest.—Anteriorly, the apices extend from half an inch to an inch and a half above the clavicle, and posteriorly as high as the seventh cervical vertebra (Fig. 1259). The anterior borders pass down behind the sterno-clavicular articulation and meet in the median line opposite the second ribs. They remain in contact as far as the fourth ribs; at this point the right border passes down to the sixth rib in the median line, thence passing outward and downward, the lower border in quiet respiration reaching the sixth rib in the mid-clavicular line, the eighth in the mid-axillary line (Fig. 1257), the ninth or tenth rib in the scapular line, and the eleventh rib near the spine; at the fourth rib the left border passes outward to the fifth costo-chondral junction, then downward and inward to the sixth rib, and then outward and downward. The lower border of the left lung is usually a little lower than the right.

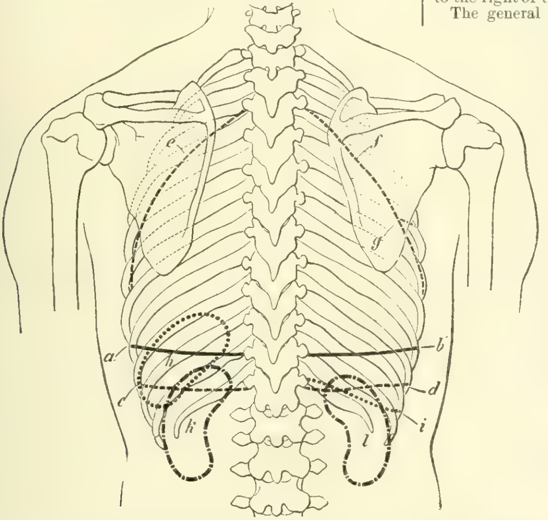

FIG. 1258.—Posterior Surface of Chest. ———, Continuous line, lower border of lungs; - - - - - - -, broken line, fissures between lobes, and line of pleura; . . . ., dotted line, spleen and liver; – - – - –, dot and dash line, kidneys. *e*, Fissure between left upper and lower lobes; *f*, fissure between right upper and lower lobes; *g*, beginning of fissure between right upper and middle lobes; *ab*, lower edge of lung; *cd*, lower border of pleural sac; *h*, spleen; *i*, lower border of liver; *k*, left kidney; *l*, right kidney. (From Sahli.)

The Fissures between the Lobes.—The fissure between the left upper and lower lobes and between the right middle and lower lobes may be indicated by a line drawn from the third dorsal vertebra to the sixth rib in the mid-clavicular line (Fig. 1258). This line corresponds roughly with the vertebral border of the scapula when the elbow is raised and the hand placed on the head. The fissure between the right upper and middle lobes meets the fissure between the upper and lower lobes at the axillary border of the scapula and passes almost horizontally forward to the junction of the fourth costal cartilage with the sternum (see Figs. 1256, 1257, 1258).

The right lung consists of three lobes, which bear the following relations to the surface of the chest: Anteriorly the upper lobe extends to the fourth or fifth rib, and the middle lobe from the fourth to the sixth rib. Laterally the upper lobe extends to the fourth rib, the middle lobe to the sixth rib, and the lower lobe to the eighth rib. Posteriorly the upper lobe extends from the apex to the spine of the scapula, the lower lobe extends from this point to the base. On the left side the upper lobe occupies the whole of the front of the chest; laterally the upper lobe extends to the fourth rib, below this the lower lobe to the base (Figs. 1256 to 1259).

Trachea and Bronchi.—The trachea deviates in its lower part a little from the median line and bifurcates behind the right edge of the sternum at the junction of the lower border of the second costal cartilage and the sternum. This point corresponds posteriorly with a point a little to the right of the spine of the fourth dorsal vertebra.

The general course of the main bronchi may be projected on the posterior surface of the chest as follows: The right bronchus starts at a point to the right of the spine of the fourth dorsal vertebra and extends in nearly a straight line to a point on the eighth rib two inches to the right of the spine. The left bronchus originating at the same point, passes outward and then downward to a point on the eighth rib three inches from the median line.

The calibre of the right bronchus is larger than that of the left, and this bronchus forms a more direct continuation of the trachea than does the left. This explains the fact that most foreign bodies which pass into the trachea through the larynx are found in the right bronchus. The bronchi are nearer to the posterior surface of the chest than to the anterior. The position and relations of the bronchi are important and help to explain the physical signs in the interscapular regions, and the differences in the signs at the apices of the lungs.

Diaphragm.—The dome of the diaphragm on the right side extends as high as the fourth intercostal space in the mid-clavicular line, in the axillary line to the sixth rib, and in the scapular line to the eighth rib. On the left side the diaphragm occupies a somewhat lower position.

Liver.—On the right side in mid-clavicular line the liver extends from the fourth space to the free border of the ribs. From the fourth space to the sixth rib the liver is separated from the chest wall by a wedge of lung tissue, below this point it is in contact with the chest wall. In the right axillary and the scapular lines the liver's upper border corresponds with the lower border of the lung (Figs. 1256 to 1258).

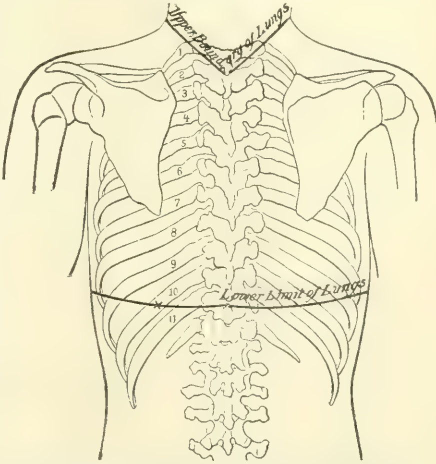

FIG. 1259.—Posterior Surface of Chest, Showing the Relation of the Upper and Lower Limits of the Lungs to the Chest Wall. (From Sahli.)

Spleen.—The spleen lies beneath the ninth, tenth, and eleventh ribs. Its upper border follows the ninth rib, and its anterior border extends to a line drawn from the tip of the eleventh rib to the left sterno-clavicular articulation (Figs. 1257 and 1258).

The lungs may be examined with the patient in either the standing, or sitting, or recumbent position. It is important that the position be a comfortable one, and that the patient's arms and legs are symmetrically placed. The patient should also be stripped to the waist.

INSPECTION.—By this method of examination the form, the size, and the movemenst of the chest in respiration are studied, and under this head the investigation of the organs of the thoracic cavity by means of the *x*-rays may also be included.

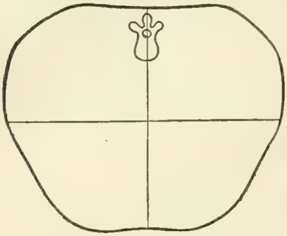

FIG. 1260.—Normal Chest. (Gee.)

Form.—The normal adult chest is elliptical in shape, the transverse diameter longer than the antero-posterior, and the two sides practically symmetrical; on measurement, however, the right is usually about half an inch larger than the left (Fig. 1260).

The supraclavicular regions are somewhat depressed, and there is generally a slight depression just below the clavicles; the remainder of the anterior surface of the thorax is convex from above downward and from side to side. The epigastric angle is nearly a right angle. The spine is usually straight, but may incline slightly to the right in the upper and middle dorsal regions. In children's chests the two diameters are nearly equal, and the chest nearly circular in form. The apex beat of the heart is often visible in the fifth intercostal space about one inch inside the mid-clavicular line.

As the result of disease deviations from the normal form of the chest occur; the more common of these are the rickety, pigeon-breast, phthisical or alar, emphysematous or barrel-shaped chests, and the deformities due to spinal disease. Changes in the contour of the chest may be demonstrated by means of the cyrtometer (see *Cyrtometer*). In addition to these general deformities there may be retraction or enlargement of the chest walls.

Retraction or *sinking in of the chest wall*, generally of the intercostal spaces, may be general or local. General retraction is caused by obstruction to the entrance of air into the larynx or trachea, foreign bodies in the larynx, diphtheritic membrane, tumors pressing on the trachea. Local retraction is the result of collapse or contraction of the lung. An example of this local retraction is seen at the apices of the lungs in phthisis, and at the bases as the result of an old pleurisy with adhesions, or of empyema.

Enlargement or *bulging of the chest wall* may be localized or may involve the whole of one side. In the former case it is usually due to abscess, tumor, or enlargement of the liver, spleen, or heart; in the latter to fluid or air in the pleural cavity. The location of the bulging often suggests the cause. General enlargement of the chest is also seen in cases of emphysema.

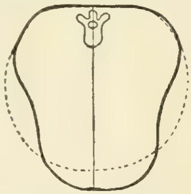

FIG. 1261.—Rickety Chest. (Gee.)

The *size of the normal chest* varies greatly; the average circumference at the level of the nipples is thirty-four inches; it may vary from twenty-eight to forty-four inches. A tape measure is a sufficiently accurate means of determining the size of the chest.

Movements.—During normal respiration the chest expands and contracts, the expansion varying from two to four or five inches. In men and in children the respiration is chiefly abdominal, in women it is of the thoracic type. The normal number of respirations is 18 or 20 per minute; women habitually breathe more rapidly than men. The mobility or expansibility of the chest may be modified by diseased conditions. Emphysema and asthma cause a generally diminished expansion; pleurisy with effusion, pneumonia, and pain, the result of dry pleurisy or injury, may produce a unilateral diminished expansion. At the apices a diminution of the expansibility is usually due to tuberculous disease, at the bases to chronic pleurisy with adhesions.

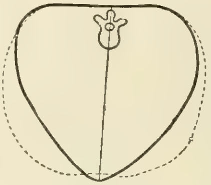

FIG. 1262.—Pigeon Breast. (Gee.)

Expansion is generally increased by exercise, and locally when one lung, or part of one lung, is called upon to do extra work; for example, the sound lung in pneumonia, or the upper lobe of the diseased side in a pleurisy with effusion. The rapidity and rhythm of the respirations are to be noted on inspection. Dyspnœa may be due to fever or to some interference with the free entrance or exit of air, in which case it is called inspiratory or expiratory dyspnœa. Orthopnœa is the term applied to breathing of such difficulty that the patient is obliged to remain in the sitting posture. Cheyne-Stokes respiration is the marked irregularity in rhythm seen in cases of uræmia and cerebral disease.

Litten's sign or the shadow on the lower portion of the chest due to the movements of the diaphragm may also be seen on inspection. To observe this phenomenon, the patient should lie on his back in a slightly raised position with his feet toward the light, which need not be very intense. The observer stands with his back to the light three or four feet from the patient and looks at the chest at an angle of about 45°. During respiration a shadowy line is seen to move over the surface of the chest from above downward. This shadow begins at the sixth rib and moves down with inspiration over two or more intercostal spaces; during expiration the shadow moves upward. This moving shadow is caused by the separation of the diaphragm from the walls of the thorax during inspiration and the returning contact during expiration.

The sign indicates the mobility of the lungs, and its absence, or restriction in the excursion of the shadow, is noted when there is fluid or air in the pleural sac, when pneumonia of the lower lobe exists, when there are pleuritic adhesions or thoracic tumors, and when the lungs are emphysematous. In very stout persons and in patients with very thick chest walls it is sometimes impossible to detect this sign.

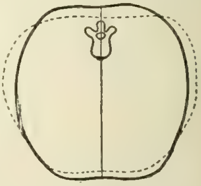

FIG. 1263.—Emphysematous Chest. (Gee.)

Examination by x-Rays.—The *x*-ray has been utilized in the examination of the chest. The use of the method depends on the fact that normal lung tissue is easily traversed by the ray, and any change in density in the lung tissue is indicated in the fluoroscope by lighter or darker areas; lighter than normal when the density of the lung is less than normal, as in emphysema or pneumothorax, and darker than is usual when the density is increased, as in tuberculosis, pneumonia, carcinoma, pleurisy, or empyema. The diaphragm can be seen to move up and down during respiration; normally it should descend from one to two and a half inches in inspiration, and any diminution in the movements of the diaphragm is suggestive of disease; frequently this limitation in the excursion of the diaphragm is one of the earliest signs of tuberculosis. In pneumonia the darkened areas are distinct, and in a central pneumonia the consolidated area may be seen before any physical signs are noted by percussion or auscultation; the movement of the diaphragm is also limited on the affected side.

In pleurisy with effusion the lower part of the chest is dark and the heart is displaced toward the sound side.

In emphysema the lungs appear brighter than normal and the diaphragm does not rise as high during expiration as it does in the healthy chest.

PALPATION.—This is the examination of the chest by the application of the hand to the chest walls: by this means irregularities in form, local points of pain or tenderness, local expansion, and vocal or friction fremitus can be appreciated. Vocal fremitus is the thrill conveyed to the hand placed upon the chest wall while the patient is speaking. It is due to the transmission downward through trachea, bronchi, and lung substance of the vibrations produced by the vocal cords in the act of speaking. The intensity of the fremitus varies in different individuals, and is always more marked in men than in women; it is diminished by anything which interferes with the transmission of the vibrations to the palpating hand. Thus thick chest walls, from muscle or fat, thickened pleura, or bronchi partially occluded with mucus diminish the fremitus. The fremitus is absent when there is fluid or air in the pleural cavity, or when the pleura is greatly thickened. Consolidation of the lungs, on the other hand, by making a better conducting medium for the vibrations, causes distinct increase of the vocal fremitus.

In some cases of bronchitis in which the breathing is of the sibilant and sonorous variety, vibrations which arise from the sibilant and sonorous rhonchi can be felt. This is called "bronchial fremitus." Friction fremitus, caused by the rubbing together of roughened pleural surfaces, is occasionally felt in cases of pleurisy.

PERCUSSION.—The sounds produced by percussion enable the examiner to determine the condition of the organ beneath the part of the chest percussed. To recognize the difference in percussion sounds, it is necessary to analyze each sound with regard to its quality, pitch, intensity, and duration.

Percussion may be either immediate or mediate. It is important that the patient should be stripped, and that the arms and legs should be in symmetrical positions. For the examination of the anterior surface of the thorax, the patient should stand erect with the hands hanging at the sides and the face pointed straight forward. For examination of the axillary regions, the hands should be placed on the head, or elevated above it; and for the examination of the posterior surface, the arms must be crossed and the hands placed on the opposite shoulders, the back slightly bowed, and the head bent forward. The object of these positions is to put the skin and the underlying muscles on the stretch, and, in the examination of the back, to increase the breadth of the interscapular space.

In immediate percussion the chest wall is struck directly by the finger or the percussor; this method is rarely used. In mediate percussion the finger of one hand, or an instrument called a pleximeter, is interposed between the chest wall and the percussing finger or percussor; this is the method commonly practised. The pleximeter or the finger, used as such, should be applied firmly to the chest wall in the intercostal spaces, and the blow of the hammer or the striking finger should be given as quickly, evenly, and as nearly at a right angle to the pleximeter as possible. For the examination of organs lying near the surface, the pleximeter should be lightly applied, and the blow of the percussor should also be light; for deep-seated organs, the pressure must be firmer and the blow more forcible.

When using the finger for the percussor, the blow must be given from the wrist and not from the elbow or shoulder. The blow should strike the middle of the pleximeter, and the finger striking the blow must be quickly lifted, as the character of the note is decidedly changed and dampened if the finger is allowed to remain in contact with the pleximeter.

It is more satisfactory to use the hands for percussion than to depend entirely on the percussor and pleximeter The hands are always ready; and, when percussing with the fingers, the observer appreciates the sense of resistance beneath the finger, in addition to the sound produced by the blow. When demonstrating the sounds produced by percussion to a large number of students, the use of hammer and pleximeter is more satisfactory. When it is necessary to compare the percussion notes on the two sides of the chest, the percussion for comparison must be made at the same point on each side, the force of the blows must be the same, the position of the patient must be so arranged that the two sides will be symmetrical, and the percussion should be made at the same period of the respiratory cycle.

On percussing a normal chest beneath the left clavicle a sound is produced, due to the vibration of the lung tissue and the thoracic walls. This sound is called the normal or pulmonary resonance, and it is recognized by the following characteristics: the quality is pulmonary or vesicular, pitch is low, intensity variable, and the duration considerable. The intensity depends on the force of the blow, on the thickness and elasticity of the chest walls, and on the volume of air contained in the portion of lung under percussion. The finger appreciates with this pulmonary resonance an elastic feeling, which is characteristic when percussing over normal lung substance.

The percussion note in the right infraclavicular region is usually slightly less resonant than that on the left side, the quality is less pulmonary, the pitch higher, the intensity less, and the duration shorter. This is probably dependent on the greater muscular development on the right side, and also on the larger amount of connective tissue in the right lung, the result of the greater size of its bronchi.

Normal pulmonary resonance is heard in the following regions: supraclavicular, infraclavicular, axillary, interscapular, and infrascapular.

If percussion is made in the lower part of the mammary region on the right side, a sound is produced differing from the normal pulmonary note in that the quality is dull, the pitch higher, the intensity less, and the duration shorter. This change in the character of the note in this region is due to the presence beneath the lung of the liver, and this solid organ modifies or dulls the normal sound produced by percussing over lung tissue.

Dulness is heard wherever the amount of lung tissue is small, or is encroached upon by solid organs, or when the normal amount of air-containing tissue is diminished as the result of disease.

In the normal chest dulness is found in the mammary region on the right side from the liver and on the left from the presence of the heart. In the infra-axillary regions, on the right from the liver and on the left from the spleen; also in the scapular regions from the excessively thick layers of muscles and bone. Disease, by producing airless tissue in the lungs, the pleura, the pleural cavity, or the chest walls, causes dulness, and, depending on the amount of airless tissue, the dulness may be slight or marked.

There is dulness in the early stages of tuberculosis, usually at the apices of the lungs, from the presence there of the tuberculous deposit. In the second stage of pneumonia there is marked dulness over the consolidated area. In cases of pleurisy with effusion, where the amount of exudate is not large, there is dulness. The same sign is produced by thickened pleura, or by chest walls much thickened by muscle or fat. Enlargements of the heart, liver, or spleen, tumors, aneurisms or abscesses, if covered by a thin layer of lung, will cause dulness on percussion. When percussing over a dull area, the finger appreciates a sense of resistance. This feeling of resistance or lack of elasticity increases as the dulness is more marked.

Flatness.—When the percussion note is entirely without resonance it is said to be flat. The quality is flat, intensity not great, pitch high, and duration short. A typical flat note can be obtained by percussing the thigh. This sound is heard when the percussion is made over solid organs, or over organs, normally air-containing, in which, as the result of disease, the air has been displaced by dense tissue or fluid. Flatness indicates absence of air. In the normal chest flatness may be obtained on the right side in the inframammary region and in the infra-axillary region below the eighth rib from the underlying liver; also in the left infra-axillary region over the spleen.

Percussion over the fluid, in cases of pleurisy with effusion, gives typical flatness, and it is in these cases that the very marked sense of resistance on percussion is so easily appreciated. Flatness on percussion may be heard in cases of pneumonia where the consolidation is complete, also in phthisis, where the consolidated area is extensive; and over tumors and enlarged solid viscera, where the mass or organ is in contact with the chest wall.

Tympanitic Resonance.—Percussion over a hollow viscus containing air elicits a drum-like or tympanitic note; the quality is tympanitic, pitch high or low, intensity usually marked, and duration variable. Typically tympany is heard on percussing over the stomach and intestines; in the normal chest it is heard only over the larynx, trachea, and in Traube's space. The variety in pitch depends on the size of the viscus and the tension of the contained air. Percussion over the stomach gives a much lower note than that over the intestines, the former being a much larger viscus than the latter. Tympanitic resonance is caused by the following conditions:

1. Large collections of air, for example over the trachea, the stomach, the colon, and small intestines; over cavities in the lung substance, especially if superficial, and over pneumothorax, when there is a free communication with a bronchus; if the opening is not free, the air in the pleural sac is under pressure, and the note on percussion is not tympanitic but dull.

2. Percussion over consolidated or compressed lung, which is in contact with a hollow viscus or air-containing organ, often produces tympanitic resonance, by conduction from the adjacent air-containing viscus. This tympanitic resonance is not uncommon over the lower lobe of the left lung even in health, and is the resonance transmitted from a stomach distended with air through the normal lung.

3. Lung that has lost its normal tension or is in a condition of relaxation is tympanitic on percussion. This occurs in cases of pleurisy with effusion, in the early stages of consolidation, pneumonic or tuberculous, and in œdema of the lungs.

4. In emphysema tympanitic percussion is common.

The presence and location of cavities may be determined by careful recognition of the tympanitic note. Several methods have been described by observers, the following being the most useful:

Wintrich's change of note. If the cavity communicates directly with a bronchus, the percussion note varies in intensity and pitch, and also in the distinctness of its tympanitic quality, as the patient opens and closes his mouth. When the mouth is open the percussion note is of greater intensity, higher pitch, and more markedly tympanitic in quality than it is when the mouth is closed.

A change in the patient's position by altering the relation of the bronchus to the cavity may also produce a change in the tympanitic quality of the percussion note.

Gerhardt's change of note depends on the presence of fluid in the cavity, the level of which is changed as the position of the patient is varied from the upright to the recumbent. In the upright position, over the lower portion of the cavity there may be dulness or even flatness on percussion, and tympany over the upper part of the cavity. This condition of physical signs is due to the fact that the fluid gravitates to the lowest part of the cavity. When the patient assumes the recumbent position the fluid level is changed, and tympany is elicited on percussion over that portion of the chest wall which was dull when the patient was erect. This sign, though seldom found, is a positive indication of the presence of a cavity.

In addition to the varieties of percussion resonance already mentioned, the following are heard in diseased conditions of the chest:

Vesiculo-Tympanitic Resonance.—The quality is a combination of normal pulmonary and tympanitic resonance, the pitch high; the more the tympanitic quality predominates the higher will be the pitch; the intensity is increased, and the duration varies. This is the resonance heard commonly in cases of emphysema, and it is often called the wooden or "bandbox" resonance. It may be heard in pleurisy with effusion over that portion of the lung which is above the fluid, and over the sound lobe in pneumonia.

Amphoric Resonance.—The quality is amphoric, pitch variable, intensity and duration are considerable. This sound is like that produced by flipping the cheek when tense, and has a peculiar musical quality. To produce the sound well the percussion should be practised during expiration, and the patient should be instructed to keep the mouth open; it is also necessary that the ear of the observer should be near the patient's mouth. This sound is heard over cavities, usually of considerable size with smooth and rigid walls, which communicate freely with a bronchus. It may more rarely be heard over pneumothorax, but only when there is free communication between the air-containing pleural sac and a bronchus. Percussion over consolidated lung, which is in contact with a large bronchus, may give amphoric resonance.

Cracked-Pot Sound.—The quality of this sound is jingling, pitch high, intensity and duration not marked. It is like the sound produced by striking the hands folded together on the knees. This sound is indicative of cavities with flaccid walls which contain air, and which communicate with a bronchus. Percussion should be practised in the same manner as has been described under amphoric resonance.

AUSCULTATION.—Auscultation is examination of the chest by the ear to hear the sounds produced in normal and abnormal conditions of the lungs during respiration, coughing, and speaking, also to detect the presence of any adventitious sounds.

There are two methods of auscultation, the immediate and the mediate. In the former the ear is placed directly on the chest, or on the chest covered with a thin cloth; and in the latter the stethoscope * is used.

The immediate method is more satisfactory for the examination of the lungs than the mediate method, except in cases in which it is necessary to localize faint adventitious sounds, or when it is desirable to auscultate those portions of the chest where it is difficult or impossible to place the ear in close contact with the thoracic wall; for example, in the supra- or infraclavicular fossæ. Under these conditions the stethoscope is of great use, not only from the fact that it can be used where the ear cannot, but also because it eliminates outside sounds and intensifies the sounds produced within the chest. The stethoscope, however, by modifying and intensifying the respiratory sounds, may cause confusion, and it is only after considerable practice that true deductions can be made as to the conditions of the lungs from the sounds heard through the stethoscope.

On auscultation over normal lung substance a rustling or breezy sound is heard with inspiration and expiration; this is the normal pulmonary or vesicular murmur. The sound heard on auscultation of the trachea and larynx is quite different from that heard over normal lung tissue:

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* For descriptions of the various forms of stethoscopes, and their modifications, see article on *Stethoscopes*.

it is a much harsher and more tubular sound, and is called laryngeal, tracheal, or tubular breathing.

Of the several theories as to the cause of the respiratory sounds, the following is the most satisfactory: A fluid, either liquid or gas, in this case air, passing with sufficient velocity through a narrow opening into a wider channel produces a sound. Such a condition obtains at two points in the respiratory system, the larynx and at the ends of the bronchioles, where they enter the alveoli of the lungs. At the larynx, the arrangement of the vocal cords is such that sounds are produced in both inspiration and expiration. At the bronchiole endings a sound is produced during inspiration, but not during expiration, as the air then is passing from a larger into a smaller space.

The laryngeal sounds, therefore, are of purely glottic origin, and may be distinctly heard over the larynx, the trachea, or the back of the neck.

The pulmonary murmur heard over the chest wall is a combination of the laryngeal sound, modified by transmission through the bronchi and lung tissue, and the sound produced in the bronchioles. The intensity of the laryngeal sound is greatly diminished by its transmission through the thin-walled smaller bronchi, which contain so many openings that the sound is much diffused. For this reason vesicular breathing is a very soft sound. The inspiratory portion is heard throughout the inspiratory act, and is composed of two elements, the glottic and the alveolar; the expiratory portion, consisting only of the glottic element, is a mere puff, oftentimes indeed it is inaudible. The fact that the expiratory sound is conducted to the ear of the examiner against the current of air producing the sound is another factor in causing the marked diminution in the intensity of the expiratory sound.

Respiratory sounds are studied by considering the quality, pitch, intensity, and duration of the sound, and also the rhythm. The inspiratory and expiratory sounds should be separately considered.

Pulmonary or Vesicular Breathing.—Normal vesicular inspiration has a breezy or rustling quality, low pitch, variable intensity, and the sound is heard throughout the inspiratory act; the quality of expiration is soft and blowing, low in pitch, and short in duration; the rhythm is unbroken, *i.e.*, there is no pause between inspiration and expiration. Expiratory sound is not always audible. Inspiratory sound is three or four times as long as expiratory. Pulmonary breathing is heard over the anterior, lateral, and posterior surfaces of the thorax.

Puerile or Supplementary Respiration.—On listening to the chests of children and also of adults, when the lungs are doing extra work, as after violent exercise or where a sound lung is doing the work for a diseased lobe in addition to its own, the normal vesicular breathing is heard much more distinctly than usual. The quality is the same as that of normal vesicular breathing, but the intensity is much increased or exaggerated. This is called "puerile," "supplementary," or "exaggerated" respiration.

Diminished Respiration.—In diminished respiration the quality is that of normal vesicular breathing, but the intensity is greatly diminished. This occurs whenever there is any interference with the circulation of the air in the lungs, or with the conduction of the sounds to the ear of the examiner.

The free entrance and exit of air may be prevented by the presence in the trachea or bronchi of secretions, diphtheritic membrane, or foreign bodies, by spasm of the bronchi, or by the pressure of tumors. Emphysema and tuberculosis, by diminishing the elasticity of the air vesicles, also restrict the free circulation of air in the lungs, and pain or great muscular weakness may so interfere with the respiratory movements that but little air enters and leaves the lungs.

The conduction of the breathing sounds to the ear may be obstructed by the presence of fluid in the pleural sac, or by thickened pleura or chest walls.

Suppressed Respiration.—Absence of respiration occurs when there is complete obstruction of a bronchus from any of the above-mentioned causes, no matter what the condition of the lung substance may be; also over fluid in the pleural sac, in pneumothorax, if the opening between the bronchus and the pleural sac is closed, and over cavities filled with fluid.

Prolonged Expiration.—At the right apex a slight prolongation of the expiration is not uncommon in normal chests. When heard in other situations, however, it is an abnormal sign and indicates a difficulty in expelling the air during expiration—in other words, an expiratory dyspnœa. In emphysema and asthma prolongation of expiration is heard all over the chest. It may also be heard in cases of bronchitis, in which the bronchi are partially occluded with mucus; and in tuberculosis, from the loss of elasticity of the lung substance due to the consolidation, it is one of the earliest physical signs.

Cogwheel or Interrupted Inspiration.—The inspiratory murmur may be interrupted or jerky in rhythm; this is sometimes heard when examining the chests of very nervous patients, and it is often one of the physical signs of early tuberculous consolidation. It occurs in this condition because, from the presence in the bronchi of deposits of tubercle, an obstruction is offered to the entrance of air into the lobules, which instead of being distended at the same time by the entering air are expanded at different times, thus producing the uneven or interrupted rhythm. Unless accompanied by other physical signs, it is of no value in diagnosis.

Laryngeal, Bronchial, or Tubular Breathing.—This breathing is normally heard over the larynx and trachea, and also may be heard over the back of the neck. The inspiration is tubular in quality, of high pitch, marked intensity, and the duration of the sound somewhat shorter than the inspiratory act. Expiration has the same tubular quality, but the pitch is higher, the intensity usually greater, and the duration as long as or even longer than that of inspiration. The rhythm is broken by an appreciable pause between the inspiratory and expiratory sounds.

When bronchial breathing is heard over those portions of the chest where normally vesicular breathing should be heard, it is a sign that the lung is in a condition of consolidation.

The occurrence of bronchial breathing over consolidated lung may be explained in this manner: The bronchial tubes are like speaking tubes, normally poor ones, as their walls are thin and interrupted by the numerous openings of the bronchioles; the laryngeal sounds in their transmission from the point of production to the chest wall through these poor conducting tubes are much diffused and changed in character. When the lung is consolidated, however, the thin walls of the bronchi are stiffened and supported by the surrounding consolidation, their resistance is increased, and the diffusion of the vibrations is diminished. In other words, consolidation makes good speaking tubes of the bronchi, and the laryngeal sounds are well conducted, with little change in their character, to the wall of the chest.

Consolidation may be due to pneumonia, phthisis, to new growths in the lung substance, to infarcts, and to compression of the lung by fluid or tumors.

Bronchial breathing is also heard over cavities which communicate freely with a bronchus, and also over dilated bronchi. In these conditions the laryngeal sounds are conducted through fairly large bronchi directly to the cavity or dilatation of the bronchus, and these bronchi are often quite close to the chest wall, and usually, in the case of a cavity, are surrounded by an area of consolidation. Should the bronchus conducting the sound vibrations to the consolidated area become occluded, no bronchial breathing will be heard. In pneumonia, for example, the bronchi may become filled with inflammatory products, and the conduction of the laryngeal sounds may be thus interrupted. If the patient be made to cough, the mucus will be expelled and the tubes cleared, then bronchial breathing will again be audible.

Broncho-Vesicular Breathing.—This, often called harsh or rude respiration, is a respiratory sound combining characteristics of bronchial and vesicular breathing. The bronchial element may predominate or the vesicular may be the more marked. In inspiration the quality is broncho-vesicular; the pitch is high in comparison with that of normal pulmonary inspiration, intensity is more marked, and duration the full length of the inspiratory act. The quality of expiration is also broncho-vesicular, pitch higher than that of inspiration, intensity greater, and the duration as long as or longer than that of inspiration. The rhythm is not broken.

This breathing is heard in the normal chest in the infraclavicular region near the sternum, and in the upper part of the interscapular region, because the bronchi are large and near the chest wall in these localities, and the sounds produced in the larynx are therefore little diffused or modified in transmission to the observer's ear.

When heard over portions of the chest where normally vesicular breathing should be heard, it is an indication of smaller or larger areas of consolidation surrounded by normal lung tissue. Therefore we may have this variety of breathing in cases of phthisis in which the infiltration is slight, or when a deep-seated pneumonia is surrounded by normal lung tissue. This variety of breathing may be heard over the portion of the lung compressed by fluid in cases of pleurisy with effusion.

The greater the infiltration or consolidation, the more marked will be the bronchial element in the respiratory sounds; the less the amount of consolidated lung, the more will the vesicular element predominate in the breath sounds.

Cavernous Breathing.—This variety of the respiratory sounds is heard over cavities, and has a hollow, blowing character, from which the sound takes its name. The quality of inspiration is cavernous, pitch low, intensity variable, and duration full length of the inspiratory act. Of expiration the quality is the same as that of inspiration, pitch is lower, intensity variable, and the duration usually longer than that of inspiration. The rhythm is not broken. Cavities over which this breathing is heard must have free communication with a bronchus; otherwise there will be an absence of breath sounds.

If the cavity is surrounded by consolidated lung, there may be a decided bronchial character to the cavernous breathing, which is called broncho-cavernous breathing; and should the cavity lie in fairly normal lung substance, the vesicular element will be marked, and a vesiculo-cavernous respiratory murmur be heard.

Amphoric Respiration.—The peculiarity of this sound lies in the musical quality, which may be imitated by blowing over the mouth of an empty bottle. The inspiration is of amphoric quality, fairly low pitch, and of some duration. Expiration is like inspiration, except that the expiratory sound is much prolonged. This breathing is heard over cavities usually large with smooth walls, and in pneumothorax or hydropneumothorax. The cavity must have free communication with a bronchus or there will be no sound during respiration. The sound indicates a cavity containing air that is not expelled on expiration.

Sibilant and Sonorous Breathing.—In sibilant breathing the quality of the sound is whistling or wheezing, and the pitch high, with marked prolongation of the expiratory murmur. Of sonorous breathing the quality is snorting or snoring and the pitch low; expiration is also prolonged. The intensity is variable. These sounds are indicative of diminution of calibre of the larger and smaller bronchi. This narrowing may be due to the presence in the bronchial tubes of viscid mucus, the product of inflammatory processes, or to the spasmodic contraction of the muscle fibres within the bronchial walls. The former condition obtains in bronchitis, the latter in spasmodic asthma.

These sibilant and sonorous sounds, or rhonchi, are heard in inspiration, in expiration, or in both; they are not constant, and often disappear if the patient be made to cough. Occasionally the sounds are so loud that they may be heard without placing the ear on the chest wall: and sometimes a fremitus may be appreciated by the palpating hand, the so-called bronchial fremitus.

Signe de Sou or Bell Sound.—This sound is heard when the chest is percussed with two coins, one used as pleximeter and the other as percussor, and the ear is applied to the opposite side of the chest. The sound transmitted through healthy lung is of a wooden quality; that heard when fluid is present is of a metallic character; while the sound transmitted through air, in pneumothorax for example, is clear and ringing, like a bell.

AUSCULTATION OF THE VOICE AND WHISPER.—The voice sounds heard over the chest on auscultation are the sounds produced by the vibrations of the vocal cords, which are transmitted through the bronchial tubes to the alveoli of the lungs and the thoracic walls. Those conditions which in any way modify the breath sounds produced in the larynx will also change the character of the voice sounds, whether spoken or whispered. The patient should count "one, two, three," but not too rapidly and in a moderately loud voice.

Pulmonary voice or normal vocal resonance is heard over normal lung substance. The quality is pulmonary; pitch low, and the intensity feeble; it is an indistinct sound seemingly distant and diffused. In men the voice sound is usually much more marked than in women and children; the intensity varies with the quality of the voice; being more marked in deep voices than in high voices. The thickness of the chest wall also modifies the intensity of the sound. Pleuritic adhesions, much adipose and muscle, fluid in the pleural sac, as well as air, all diminish the intensity of the vocal resonance.

If the pleural effusion is large, and over consolidated lung, if the bronchi are occluded, the vocal resonance is absent.

In the infraclavicular regions the vocal resonance is usually increased; this is also true of the voice sounds heard in the interscapular space. In the early stages of pneumonia and in phthisis, in which the amount of consolidation is slight, the voice sounds are increased in intensity: also over cavities lying near the chest wall.

If the person examined be asked to whisper "one, two, three," the examiner hears during expiration the normal bronchial whisper. The sound resembles the normal expiratory sound; it is feeble and blowing in quality, and may oftentimes be inaudible.

When there is moderate consolidation the whispered voice is much more intense, and is not unlike the respiratory sound heard in broncho-vesicular breathing.

Laryngeal or Bronchial Voice.—Bronchophony. This may be normally heard over the larynx and trachea. The quality is laryngeal, the pitch high, intensity great, and the distinctness marked; the sound seems near, there is a marked thrill, and a sensation, like a shock or concussion, is conveyed to the ear. When the lung is consolidated or compressed, so that the bronchial tubes have been made good conductors of sound, bronchial voice is heard at those points of the chest wall which lie above the consolidated area. It may also be heard over cavities, and sometimes over fluid.

Ægophony, which is a modification of bronchophony, has the same intense character, but in addition has a bleating or tremulous quality, from which it derives its name, the quality being likened to the bleating of a goat. It is best brought out by having the patient repeat words like "brant" or "rant." It is significant of a small amount of fluid in the pleural sac, and is heard in pleurisy with effusion, where the effusion is not great and where a thin layer of fluid lies between the lung and the chest wall. It is not a common sign. The most usual location for this sign is at the angle of the scapula.

Pectoriloquy, another variety of bronchophony, is that voice sound where, in addition to the voice, the articulation of the words is distinctly appreciated. It can be heard best when the patient whispers, and is indicative of the presence of a cavity; it may also be heard over consolidated lung, where the consolidated area is in contact with a large bronchus.

Amphoric voice has the quality of amphoric breathing, and is heard when there is air in the pleural sac, or over large cavities; the same conditions of the lung in which amphoric percussion note and breathing may be heard.

Metallic tinkle is the sound produced, during breathing and talking in cases of hydropneumothorax, by the dropping of fluid in the pleural sac. This sound is also heard when there is a large cavity in the lung, containing fluid.

When listening over a cavity, after the patient coughs, a suction-like sound may frequently be heard. This is caused, in all probability, by the sudden expansion of the cavity, after the violent expulsive effort of coughing, and the rush of air back into the cavity. It is a sign distinctive of the presence of a cavity in the lung substance, which is in free communication with a bronchus. Should the bronchus become occluded the sound would not be heard.

RÂLES.—Râles are adventitious sounds, which are never heard in the normal chest. They may be produced in the larynx, trachea, bronchi, alveoli, in the pleura or in cavities. The character of the râle depends entirely on the point at which the sound is produced.

Crepitant Râles.—The finest of all râles is the crepitant râle. This is a fine, dry, crackling sound, which is heard only at the end of inspiration and does not disappear when the patient is made to cough; coughing in fact often makes the sound more intense. The sound is likened to the crackling of burning salt, or of hair rubbed between the fingers. It is heard in puffs and seems close under the observer's ear.

There are two theories as to the production of the crepitant râle; one considers the sound a pure friction sound produced in the pleura by the rubbing of the roughened surfaces against one another; the other believes that the sound is caused by the separation of the adhering surfaces of the alveoli, when the air enters the alveoli during inspiration.

The first theory explains satisfactorily the production of the fine crepitations heard in dry pleurisy; whereas the latter seems the more satisfactory explanation of the crepitant râles heard in the early stages of pneumonia before consolidation is complete, and again in the later stages, when resolution is beginning. At both of these periods the walls of the air vesicles are held in contact by the products of inflammation, and are separated by the entrance of air at the end of inspiration.

Crepitant râles are heard in pneumonia, in phthisis, in dry pleurisy, and at times after a full inspiration at the bases of lungs of patients who breathe superficially and are confined to bed.

Subcrepitant râles are fine, moist, crackling or bubbling sounds heard with inspiration, expiration; or with both, and which disappear when the patient coughs. These sounds are probably produced by small bubbles of air breaking through the mucous or inflammatory exudate in the bronchioles. They are commonly heard in bronchitis, pneumonia, phthisis and œdema of the lungs.

Coarse, Mucous, or Bronchial Râles.—The cause of these sounds is the same as that of subcrepitant râles, but the point of production is in the larger bronchi, where more inflammatory exudate is collected, through which during respiration a larger volume of air must pass. The same pathological conditions are indicated by the presence of these sounds, viz., bronchitis, pneumonia, phthisis, etc.

In cavities containing fluid, when the bronchus communicating with the cavity opens below the level of the fluid, gurgling râles are produced by the entrance and exit of air; the quality of these sounds is moist and coarse, and is suggestive of large bubbles of air passing through fluid.

Friction Sounds.—When the surfaces of the pleura are inflamed and move during respiration upon one another, a rubbing or creaking sound is produced. These friction sounds may be fine and dry, like crepitant râles; they are heard with expiration as well as with inspiration, they may be moist and coarser and resemble subcrepitant râles, or they may be creaking and rubbing in quality. The sound is close under the ear, and may be intensified by making firm pressure with the stethoscope; also, in contradistinction to râles produced in the lung substance, they do not disappear when the patient coughs.

Dry pleurisy, pleurisy with effusion, when the fluid is absorbed, pneumonia and phthisis, all may cause the presence of friction sounds.

Succussion.—This is a splashing sound produced by shaking the patient in cases in which there are air and fluid in the pleural sac, or in which there is a large cavity containing air and fluid. It is not uncommonly heard over the normal stomach when it is partially filled with fluid.

PHYSICAL EXAMINATION OF THE HEART.

The same methods are employed in examining the heart that are used in examining the lungs; and thus the size of the heart, the character of its impulse, the rhythm, and the sounds (both normal and abnormal) may be determined.

Topographical Anatomy.—The heart is placed somewhat more to the left of the median line than to the right. The anterior surface, that which is in contact with the chest wall, is composed chiefly of the right auricle and ventricle, and of a narrow strip of the left ventricle. The base of the heart, formed by the right auricle, the great vessels, and the left auricular appendix, lies at the level of the upper border of the third costal cartilage, and extends nearly an inch to the right and left of the sternum (Fig. 1256).

The apex, the tip of the left ventricle, lies normally in the fifth intercostal space about one inch within the mid-clavicular line.

The right edge, which begins at the third costal cartilage on the right of the sternum and extends to the junction of the fifth costal cartilage with the sternum, is composed of the right auricle. The line of the right edge is somewhat curved with the convexity directed to the right.

The inferior edge is formed by the right ventricle and the apex of the left; it extends from the fifth costo-sternal junction to the apex of the heart.

The left edge of the heart is made up entirely of the left ventricular wall, and extends from the apex to the upper border of the third rib, about one inch to the left of the sternum. The groove which separates the right auricle from the right ventricle may be indicated by a line drawn on the surface of the chest from the third left to the sixth or seventh right costo-sternal junction. The ascending part of the aorta is in closest relation to the chest wall in the second right intercostal space, slightly beyond the edge of the sternum. The pulmonary artery is in the corresponding position to the left of the sternum (Fig. 1256).

The orifices of the heart are situated beneath the left half of the sternum, and near together. The aortic and pulmonary at the level of the third costal cartilage, the mitral and tricuspid at the level of the fourth and fifth respectively.

INSPECTION.—The location of the apex beat and its character—that is, whether the visible impulse is well defined, diffused, heaving, or wave-like—may be observed by inspection. Bulging or retraction in the præcordial region, pulsation of the vessels in the neck, and pulsation in the epigastrium may also be noted.

Normally the site of the apex beat is in the fifth space about one inch within the mid-clavicular line; it is well defined and localized (Fig. 1256). Often the apex beat is not visible on account of the thickness of the chest wall, the depth of the chest and consequently the distance the apex may be from the thoracic wall, or because the apex is separated from the chest wall by lung tissue as in emphysema.

Bulging of the præcordium may be caused by hypertrophy of the heart, by fluid in the pericardial sac, by aneurism (in which case the bulging is situated at the base of the heart), or by tumors. Retraction, usually in the third, fourth, and fifth left intercostal spaces, and occurring with the systole, may be due to adherent pericardium or to atmospheric pressure; this is the more common cause, and it occurs in hypertrophy or dilatation, in which conditions the volume of the heart is much decreased during systole and the pressure of the air causes a sinking in of the intercostal spaces. Pulsation of the vessels of the neck may be either venous or arterial in origin; in the former case the result of an incompetent tricuspid valve, and in the latter due to an insufficient aortic valve.

Pulsation in the epigastric region is generally due to the pulsation of the right ventricle transmitted through the liver to the surface. Should the right ventricle be hypertrophied, the epigastric pulsation is much more marked. This is noted in emphysema, and in those cases of valvular disease of the left heart which cause the right side to hypertrophy in the attempt to compensate for the lesion. Epigastric pulsation may also be caused by the normal pulsation of the abdominal aorta, by aneurism of the abdominal aorta, or by a pulsating liver.

Palpation.—Many of the observations made by inspection may be confirmed by palpation, and may often be more easily appreciated. The location of the apex beat, often invisible, can usually be felt, and if not palpable when the patient stands erect, may become so if the patient is made to lean forward. In addition to the site of the apex beat, its regularity and force can be observed, and the presence of thrills determined. Changes in the location of the apex are suggestive of certain abnormal conditions. Hypertrophy and dilatation of the left ventricle and fluid or air in the right pleural cavity displace the apex downward and to the left.

Congenital malformations, retraction of the right lung from old pleurisy or tuberculosis, and fluid or air in the left pleural sac dislocate the apex to the right.

Retraction of the left lung, or pressure from below, as in ascites, tympanites, enlargement of the abdominal organs or tumors, displace the apex upward. Downward displacement is usually the result of aneurism of the aorta or of emphysema.

The regularity or rhythm may be changed by disease. The heart may be irregular in the force and frequency of its beats; and it may intermit or drop out a beat from time to time.

The force of the heart beat may be increased or diminished. It is diminished by any of the exhausting diseases: by myocarditis, by lesions of the valves causing dilatation of the cavities and weakening of the cardiac muscle, by the presence of fluid in the pericardium, by the presence of lung tissue between the chest wall and the apex, as in emphysema, or by very thick chest walls.

Hypertrophy of the ventricles, over-exertion, or thin chest walls increase the force of the apex beat.

Where the weakness or force is due to changes in the thickness of the thoracic wall or to the interposition of lung tissue between the costal wall and the apex, the weakness or strength is only apparent, and the real strength or weakness must be determined by the examination of the pulse.

Thrills may be detected by the palpating hand. When noted at the base of the heart and systolic in time they are suggestive of aneurism of the aorta or of aortic stenosis. At the apex a systolic thrill may occur in mitral insufficiency; and a presystolic thrill is observed in mitral stenosis.

Pericarditis occasionally causes a rubbing, which may be appreciated on palpation—the so-called pericardial friction fremitus. It is usually to be felt at the base of the heart in cases of dry pericarditis, and occurs with systole and diastole.

Percussion.—Percussion of the præcordium to determine the size of the heart may be practised in the ordinary manner or auscultatory percussion may be used. Both of these methods have their advantages, and may be used to supplement each other.

By this means of examination not only the fact that the heart is enlarged can be made out, but the part of the heart which is the site of hypertrophy may be determined.

The superficial and deep areas of cardiac dulness should be marked out (Plate XXII., Fig. 1). The superficial area of cardiac dulness is that portion of the heart which is not covered by lung substance in full inspiration. It is somewhat triangular in shape and is bounded internally by the left edge of the sternum, externally by an oblique line drawn from the fourth costal cartilage at its sternal junction to the fifth space just within the apex, and below by a line drawn from this point to the end of the sternum. In marking out this area the examiner is finding in reality the edges of the lungs, and, as the layer of lung tissue overlying the heart is thin, percussion must be light; for this examination finger percussion is most satisfactory. If the volume of the lungs is increased as in emphysema, the superficial area of cardiac dulness will be much diminished; unless the heart is also hypertrophied, in which case the borders of the lungs may be pushed back, and an apparently normal area of superficial cardiac dulness will be found on percussion. The deep area of cardiac dulness is the dulness detected by percussing over the edges of the heart; as there is, however, a thick layer of lung between the right and left borders of the heart and the chest wall, the area, as made out by digital percussion, does not accurately correspond with the outline of the heart, and, to determine with more exactness the right and left edges of the heart, auscultatory percussion may be employed. This method of examination was introduced by Dr. Cammann, who also devised the binaural stethoscope, and depends upon the fact that every organ has a percussion note peculiar to itself. When ordinary digital percussion is practised, the note produced is conveyed to the ear through the air, and the sound is thus more or less diffused and changed in character; when, however, the sound of the percussion note is brought to the ear direct by the use of the stethoscope, differences in quality and intensity are readily recognized.

To practise this method of percussion, the bell of the stethoscope, held by an assistant or the patient, should be placed over the organ, the dimensions of which are to be determined, at the point where the organ comes in contact with the thoracic or abdominal walls, and moderate percussion be made beginning at some distance from the point where the stethoscope is placed and gradually approaching it. When the pleximeter or finger reaches the point on the surface of the chest or abdomen below which the border of the organ lies, the percussion note changes abruptly, becomes much more marked in intensity, and usually higher in pitch. In mapping out the outline of the heart, it is best to find a number of points on the border of the heart at the extremities of its diameters, the vertical, transverse, and right and left oblique; these diameters intersect at a point near the centre of the heart. The eight points found, on being joined, give a fair outline of the heart. The vertical diameter is drawn parallel to the left border of the sternum; the transverse at right angles to the vertical diameter through its centre; the right oblique diameter is drawn, on the line from the right shoulder to the apex, from the right auricle to the apex; and the left oblique at a right angle to the latter and through its centre.

It is claimed that a skilful examiner can so accurately mark out the cardiac outlines on the cadaver that sharp-pointed steel needles driven through the chest wall at the given points will pass between the cardiac muscle and the pericardium.

On the living subject the outline cannot be so exactly determined, as the heart is constantly changing its size in systole and diastole. It is found, however, that the sum of the diameters in a large number of cases of adult males averaged sixteen and five-sixth inches, and this for the purpose of comparison is of use, though the length of the diameters considered singly is worthless.

In addition to determining the size of the heart and the location of its borders, this method of examination may be used to locate the edges of the liver in the normal subject, or when there is fluid in the pleural sac or abdominal cavity; also when a consolidated right lobe is in contact with the liver. The size of the spleen can be made out in ascites, or when in contact with an enlarged liver, provided that at some point the spleen is in contact

EXPLANATION OF
PLATE XXII.

EXPLANATION OF PLATE XXII.

(In all the figures the blue color indicates the superficial, and the red color the deep, cardiac dulness. The liver dulness is also indicated by the blue color.)

Fig. 1.—Area of Superficial and Deep Cardiac Dulness in Normal Conditions.

Fig. 2.—Area of Heart Dulness in Dilatation of the Right Ventricle. The increase in area of dulness is almost entirely to the right of sternum.

Fig. 3.—Area of Heart Dulness in Dilatation of the Left Ventricle. The increase in dulness is limited to the left side of the sternum.

Fig. 4.—Area of Heart Dulness in Dilatation of Left Auricle and Ventricle, with Uncovering of the Pulmonary Artery. (*a*) Deep cardiac dulness, right and left ventricles; (*b*) superficial dulness, the left auricle; (*c*) dulness due to pulmonary artery.

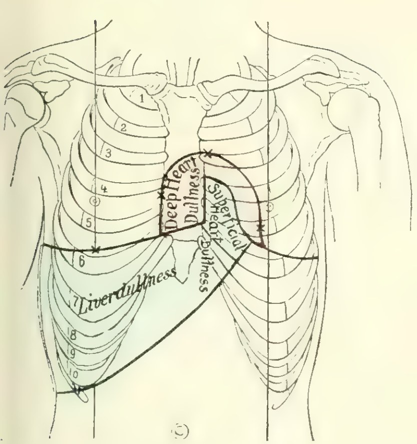

Fig. 1.

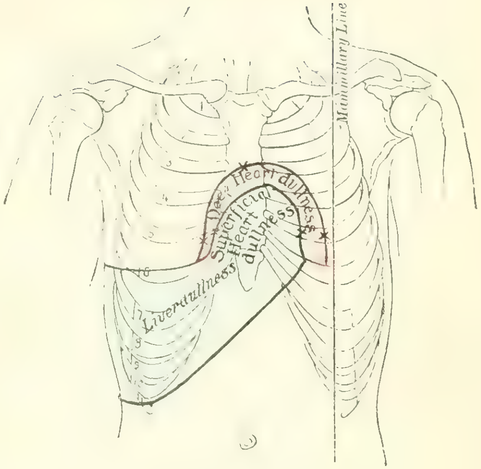

Fig. 2.

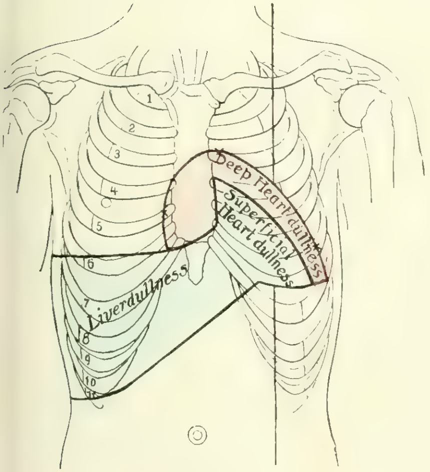

Fig. 3.

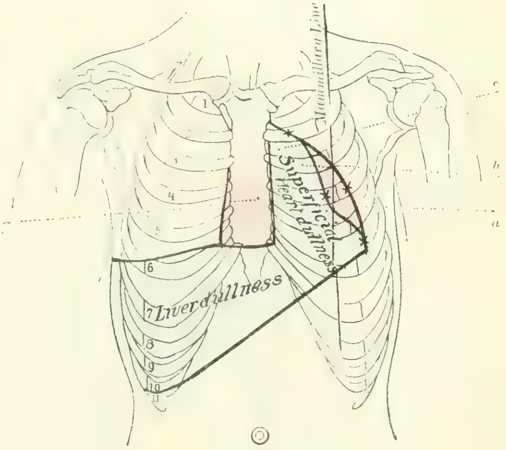

Fig. 4.

GRAPHIC REPRESENTATION OF SUPERFICIAL AND DEEP CARDIAC DULNESS
IN THE NORMAL HEART AND IN HYPERTROPHY
AND DILATATION

From Sahli's "Lehrbuch der klinischen Untersuchungs-Methoden," etc.

with the parietal wall. The kidneys may be mapped out with the exception of the inner border.

Another form of auscultatory percussion has come into use with the invention of the phonendoscope. Here instead of percussing, the surface of the chest in the neighborhood of the organ under examination is gently scratched with the finger. This produces a sound the quality of which, as well as the intensity and pitch, instantly changes when the density of the organs beneath the surface changes. It is merely a modification of auscultatory percussion, but is perhaps capable, in skilful hands, of giving even more definite information in regard to the size of the solid organs of the body, of tumors, the level of fluid exudates or transudates, and the line of contact between tumors and solid organs, or between solid organs and fluid.

As in percussing the lungs, so in the examination of the heart by percussion, much information may be gained by noting the sense of resistance beneath the finger in contact with the chest wall.

If by either of the methods of percussion described the area of the heart dulness is found increased, it is suggestive of hypertrophy of the heart muscle, and the locality of the dulness indicates the portion of the heart which is enlarged; of fluid in the pericardium; of aneurism, or of a consolidated lung or tumor displacing the heart.

Should the area of cardiac dulness be diminished, the usual cause will be found in an emphysematous condition of the lungs.

AUSCULTATION.—By auscultation the character, rhythm, and point of maximum intensity of the normal heart sounds are observed, any changes in the intensity or rhythm are noted, and the presence of any abnormal sounds or murmurs is detected. In this examination the immediate or mediate method may be employed. The mediate is, however, the more common, and the use of the stethoscope enables the examiner to localize the area of the maximum intensity of the sounds more exactly; it also intensifies the sounds, so that sounds inaudible to the ear may by its aid be clearly heard.

Two sounds are heard on auscultation: the first, or systolic sound, occurring with the systole of the heart, somewhat dull and booming in character, and resembling the syllable "tubb"; the second, or diastolic sound, occurring with the diastole of the heart, short, quick, and snappy in character, like the syllable "dupp."

The first and second sounds are separated by a short pause, and a longer pause occurs between the second sound and the succeeding first sound. This rhythmical recurrence of the first and second sounds with the interposed pauses makes up the cardiac cycle.

The first sound is produced by the closure and tension of the auriculo-ventricular valves and the tension of the walls of the ventricles; it is, therefore, a composite sound made up of several elements. The second sound is caused by the sudden closing of the aortic and pulmonary valves.

Normally these sounds recur in rhythmical sequence, and may be heard all over the præcordium. There are, however, areas where the individual sounds may be heard with greater distinctness. For example, the first sound may be heard most clearly at the apex, and not immediately over the point of production, the location of the mitral and tricuspid valves. This area at the apex is called the mitral area.

The aortic element of the second sound is most clearly heard in the aortic area, the second right intercostal space near the sternum; and the pulmonary element in the second left intercostal space, the pulmonary area. At the apex the quality of the systolic sound is soft and booming, the pitch is low, the intensity marked, and the duration long. The quality of the second sound is clicking or sharp, the pitch is higher than that of the first sound, the intensity less, and the duration shorter.

At the base the intensity of the first sound is diminished, and that of the second sound increased. As a rule, the second sound is heard more distinctly in the aortic area than in the pulmonary; in other words, the aortic element of the second sound is normally the louder.

Disease may cause changes in the normal heart sounds, which modifications are noted in the quality, intensity, duration, and rhythm.

The quality of the first sound may be impure or rough, and there may be reduplication of the first sound, which is caused by the non-synchronous contraction of the ventricles and closure of the auriculo-ventricular valves.

The intensity of the first sound is much increased in cases in which there is hypertrophy of the left ventricle, in acute febrile diseases, and in patients with very thin chest walls. Diminution in the intensity is noted in emphysema, in patients with very thick chests, in cases of pericarditis with effusion, in all exhausting diseases, and in dilated heart.

In hypertrophy the duration of the first sound may be prolonged, even to the point of sounding like a murmur; and in dilatation this sound is so shortened that it may be mistaken for the second sound. The same shortening of the first sound is often observed in cases of mitral stenosis.

The rhythm is often irregular or intermittent; this is particularly marked in cases of mitral stenosis and in dilated heart. The aortic element of the second sound, or the aortic second sound as it is called, is accentuated in any disease which causes an increase in the blood pressure in the aorta and systemic circulation; in other words, when the arterial tension is high, or when there is an increased amount of blood in the aorta, as in aneurism or dilatation of the aorta. When the action of the heart is weak, as in dilated heart, in fevers, and in myocarditis, the amount of blood and the tension in the aorta are diminished, and the intensity of the aortic second sound is lessened. The pulmonic second sound is accentuated when the pulmonary circulation is under increased tension; in mitral disease, either stenosis or insufficiency of the valve, and in pneumonia or emphysema. When the tension in the pulmonary circulation is low, the second sound in the pulmonary area is diminished in intensity.

There is not uncommonly a reduplication of the second sound, which is due to the fact that the aortic and pulmonary valves do not close at the same moment. This occurs when the tension of the blood, or blood pressure, is unequal in the systemic and pulmonary circulation. It is frequently observed in mitral stenosis.

In addition to the normal heart sounds, other sounds may be heard which are the result of diseased conditions of the heart or vessels. These abnormal sounds may be produced either within or without the heart or in the great vessels, and are therefore called endocardial, exocardial, or vascular murmurs. In listening to a murmur, in order to decide upon its nature and the lesion upon which its production depends, it is necessary to note the time of the cardiac cycle at which the murmur is heard, its point of maximum intensity, the quality of the sound, and the direction in which it is transmitted.

Exocardial Murmurs.—These sounds are produced by the rubbing together of the surfaces of the pericardium made rough by inflammation, or by the movement of the pulmonary pleura against the pericardial sac; hence these sounds are called pericardial friction sounds or murmurs or pleuro-pericardial sounds.

Pericardial murmurs occur in pericarditis, and they are heard with both the systole and the diastole of the heart. From this fact they are often spoken of as "see-saw" or "to-and-fro" murmurs. The murmur is usually loudest at the base of the heart and along the line indicating the auriculo-ventricular groove. The quality is rubbing and creaking, not of marked intensity and often very faint; the intensity may frequently be increased by pressure on the chest wall with the stethoscope. The sound is near the ear, and is not transmitted.

Pleuro-pericardial frictions or murmurs occur in cases of dry pleurisy involving the pleura of the pericardial sac and the adjacent lung. The sounds are not synchronous with the heart action, but occur with the respiratory movements, and may disappear when the patient holds his breath; they are usually heard loudest over the borders of the ventricles, when respiration is deep. The quality is rubbing, the intensity not marked, and it may be increased by pressure with the stethoscope.

Endocardial Murmurs.—Endocardial murmurs may be due to gross changes in the valves or lining membrane of the heart, or to changes in the quality of the blood. In the first case they are called organic, and in the second functional, hæmic, or inorganic murmurs respectively.

Organic Endocardial Murmurs.—For the production of a murmur two factors are necessary: force and rapidity of the blood current, and narrowing or change in calibre of the passages through which the blood flows.

The blood normally flows with force and rapidity through a passage with smooth walls, and of even or gradually diminishing calibre. When, as the result of disease, the cusps of the valves do not open properly to allow the blood to flow through, or when the curtains of the valves do not close perfectly and so allow the blood to flow back through the opening, a sudden diminution in the calibre of the passage occurs. Thus the two factors for the production of a sound or murmur, the blood current passing with force and rapidity through a narrow opening into a wider space, are present within the diseased heart.

Should the velocity and force of the blood current be diminished, as the result of a weak heart, when a diminution in the calibre exists, either there will be no murmur or a murmur of slight intensity will be heard. The valves on the left side of the heart are those most commonly the seat of organic disease in adults. In early infant life and in intra-uterine life the valves of the right heart are usually those affected.

Inorganic, Functional, and Hæmic Murmurs.—In addition to the organic valvular lesions which render the valves unfit for the work they are destined to perform, the valves may be rendered incompetent on account of a dilated condition of the muscular walls of the heart and a consequent widening of the orifices, which the cusps of the valves are unable to fill in and close. This inability to close the dilated auriculo-ventricular orifice, for example, is due to the fact that the cusps of the mitral valve are too small, and also to the fact that the papillary muscles are displaced by the dilatation of the heart and so prevent the cusps from closing perfectly.

An increased blood pressure in the aorta or pulmonary artery, or a loss of elasticity of the arterial coats, which causes a dilated condition of the vessels, may allow a regurgitation of blood at the aortic or pulmonary orifices. Murmurs due to these causes are spoken of as inorganic, or the result of relative insufficiency of the valves.

Changes in the character of the blood may also produce sounds, to which the name "hæmic" or "functional" murmurs is given.

Organic Murmurs.—Sounds due to organic lesions are heard during either the systole or the diastole of the heart, and are therefore spoken of as systolic or diastolic murmurs. Those murmurs which occur during the diastole, but which end at the beginning of the systole, are called "presystolic" murmurs.

Systolic murmurs, heard loudest in the aortic and pulmonary areas, are due to a stenosis or obstructed condition of the aortic or pulmonary orifices. Systolic murmurs heard at the mitral or tricuspid areas are due to incompetent mitral or tricuspid valves, which allow a regurgitation of blood through them. Diastolic murmurs in the aortic and pulmonary areas are produced by blood regurgitating through an incompetent aortic or pulmonary valve. Murmurs diastolic in time and heard in the mitral and tricuspid areas are caused by an obstructed or stenotic mitral or tricuspid valve.

The relative frequency of these murmurs is in the following order (Broadbent): mitral regurgitation, mitral stenosis, aortic regurgitation, aortic stenosis, tricuspid regurgitation, tricuspid stenosis, pulmonary stenosis, pulmonary regurgitation. To take up the consideration of the murmurs in the order of their frequency:

Mitral Systolic Murmur.—Mitral valve incompetent, blood regurgitates into left auricle during systole of left ventricle. The most common cause of incompetence of the mitral valve is rheumatic endocarditis. Myocarditis, dilated left ventricle from any cause, or the infectious diseases may also produce this lesion.

The murmur occurs with the systole of the heart; the quality is soft and blowing like a whispered "who," pitch is low and intensity not loud; the duration is long. Area of maximum intensity at the apex; the murmur may be localized or may be transmitted toward the left into the axilla; it may also be heard in the left interscapular region along the internal border of the scapular.

Mitral Presystolic Murmur.—The mitral valve is stenosed or obstructed, and the blood is therefore hindered in its passage from the left auricle to the left ventricle during the auricular systole. The cause in nearly all cases is rheumatic endocarditis.

The murmur occurs during the auricular systole; toward the end of the long pause it becomes gradually louder and louder, and ends with the first sound of the heart. The quality is harsh, rough, and rolling, intensity marked, the area of maximum intensity usually small and just within the apex. This murmur is not, as a rule, transmitted.

Aortic Diastolic Murmur.—Aortic valve incompetent, the blood therefore regurgitates into the left ventricle during the period of diastole. Rheumatic endocarditis is a common cause of this lesion; also atheromatous changes in the aorta and the cusps of the valve, as well as dilatation of the orifice.

The murmur occurs with and replaces the second sound of the heart; it is soft and blowing in quality, often almost musical; generally of rather high pitch, of variable intensity and short duration. The area of maximum intensity varies, it may be most marked in the aortic area; sometimes to the left of the sternum in the second, third, or fourth intercostal space; and at times at the tip of the sternum. It is transmitted across and down the sternum to the ensiform cartilage, and to the apex.

Aortic Systolic Murmur.—Aortic valve stenosed or obstructed, the blood hindered in its passage during the systole of the left ventricle from the ventricle into the aorta. This murmur may be due to true stenosis of the orifice resulting from rheumatic endocarditis or atheromatous changes. It may be caused by atheroma of the first part of the aorta, by thickening and roughening of the aortic cusps, and sometimes as the result of aneurism and rupture of the valves.

The murmur occurs with or replaces the first sound. Its quality is harsh and rough; it may, however, at times be soft, the intensity is usually marked and the duration long. Heard with maximum intensity in the aortic area, and transmitted up the vessels of the neck. It may sometimes be heard all over the præcordium, and in the second, third, and fourth intercostal spaces on the left side near the vertebral column.

HYPERTROPHY AND DILATATION OF THE HEART.—Hypertrophy of the heart is a thickening of the walls of the heart which may involve the walls of all the cavities or be limited to those of one. Dilatation is an increase in the capacity of the cavities of the heart; as in hypertrophy one or more of the cavities may be involved at the same time.

Hypertrophy and dilatation may occur together or separately. With hypertrophy there is usually a certain amount of dilatation. Hypertrophy results from the effort of the heart to do more work than normal. This demand for extra work may be due to excessive exercise, to functional causes, for example exophthalmic goitre, to mechanical defects in the circulatory system, to valvular disease, or to increased resistance in the peripheral or in the pulmonary circulation, depending on Bright's disease, chronic bronchitis, or emphysema. The endeavor of the heart to overcome any of the valvular lesions by hypertrophy is an effort of the organism to supply extra force where extra work is needed. If the hypertrophy is sufficient to overcome the symptoms arising from the valvular lesion, the lesion is said to be

EXPLANATION OF PLATE XXIII

EXPLANATION OF PLATE XXIII.

(In all the figures the blue color indicates the superficial, and the red color the deep, cardiac dulness. The shaded wedges show the area over which the murmurs are heard, and indicate by their thickness the intensity of the sound.)

FIG. 1.—Mitral Insufficiency. Showing slight hypertrophy of left ventricle, and marked hypertrophy of the right side of the heart. Accentuation of pulmonic second sound, indicated by the sign ∪∠ at the base. Murmur heard at apex with maximum intensity, transmitted to the left (>) and diminishing.

FIG. 2.—Mitral Stenosis. Left ventricle of normal size. Hypertrophy of left auricle and of right side of heart. Pulmonic second sound accentuated. Maximum intensity within apex: murmur increasing to first sound (<). Not transmitted.

FIG. 3.—Aortic Insufficiency. Left ventricle greatly hypertrophied. Right side of heart normal in size. Murmur heard over a considerable area, at times with maximum intensity at base in aortic area, at times at lower end of sternum. No accentuation of second sounds.

FIG. 4.—Aortic Stenosis. Left ventricle somewhat hypertrophied. No changes on right side of heart. Murmur heard with maximum intensity in aortic area, transmitted up into cervical vessels.

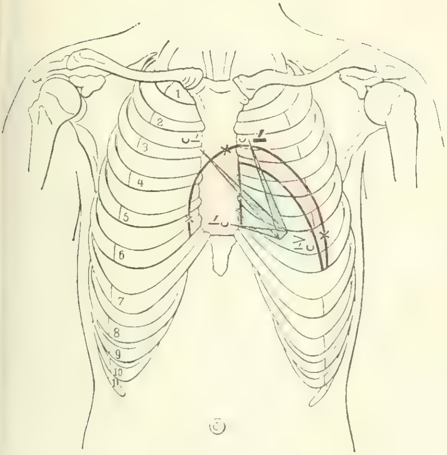

FIG. 1.

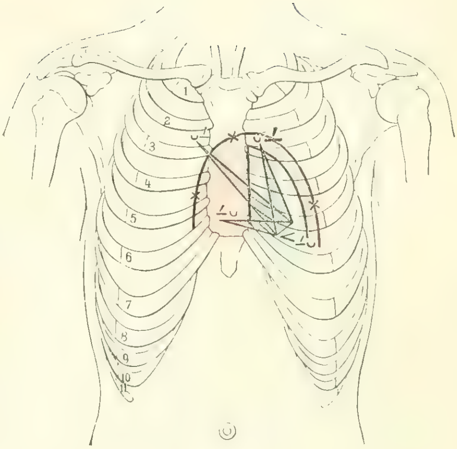

FIG. 2.

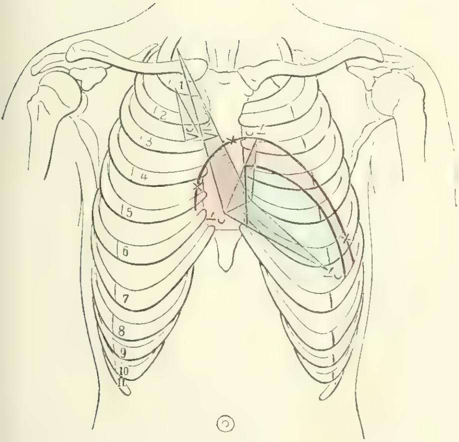

FIG. 3.

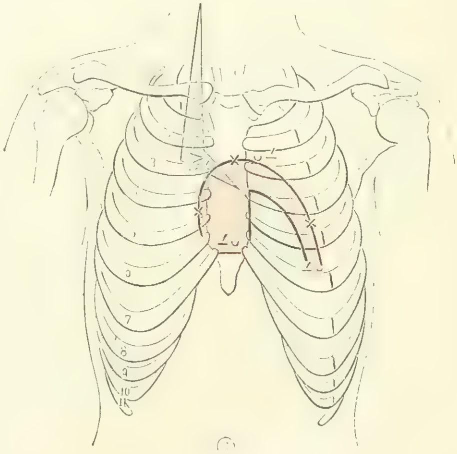

FIG. 4.

GRAPHIC REPRESENTATION OF THE PHYSICAL SIGNS FOUND IN THE FOUR MOST COMMON VALVULAR LESIONS OF THE HEART

From Sahli's "Lehrbuch der klinischen Untersuchungs-Methoden," etc.

compensated. This compensation results from the hypertrophy of the walls of the cavity immediately behind the obstructed orifice.

After the hypertrophy has existed for some time, the heart muscle fails to respond to the extra demand made upon it and becomes weakened; this is followed by a dilatation of the cavity and a failure of compensation.

THE PHYSICAL SIGNS OF HYPERTROPHY OF THE LEFT VENTRICLE (Plate XXII., Fig. 3).—*Inspection.*—Bulging of præcordium, especially in children and adults with thin chest walls; apex displaced downward and to the left of the mid-clavicular line; a heaving impulse over the præcordium.

Palpation.—A slow, heaving, and forcible apex beat. Pulse strong, and tension increased.

Percussion.—Deep cardiac dulness extends more to the left and downward than normal; where the increase in deep cardiac dulness is very great there is probably dilatation with the hypertrophy.

Auscultation.—First sound prolonged; occasionally there is a murmur to be heard, this occurs where the dilatation of the ventricle and auriclo-ventricular orifice causes an incompetent mitral valve. The aortic second sound is usually markedly accentuated; it is clear and ringing, where the cusps of the valves are normal; muffled and duller where atheroma has caused a thickening of the valves. There may also be a reduplicated second sound. In cases of emphysema the physical signs of hypertrophy are not marked; this is due to the voluminous lungs, which lie between the heart and the chest wall, and which interfere with the physical signs elicited by inspection, palpation, and percussion, especially in the latter method of examination, where apparently the area of superficial cardiac dulness is normal. In cases of emphysema where there is no hypertrophy of the heart the cardiac dulness is always diminished.

THE PHYSICAL SIGNS OF HYPERTROPHY OF THE RIGHT VENTRICLE (Plate XXII., Fig. 2).—*Inspection.*—Bulging of the lower part of the præcordium, with pulsation in intercostal spaces to the right of the sternum and in the epigastrium. The apex beat is somewhat displaced to the left by hypertrophy of the right ventricle.

Palpation.—Heaving pulsation and the dislocated apex beat are also detected by this means of examination.

Percussion.—Dulness may extend for an inch or more to the right of the sternum from the enlargement of the right auricle.

Auscultation.—Sounds are not much changed unless there is dilatation. There may be reduplication of the pulmonary second sound.

DILATATION OF THE HEART gives these physical signs: *Inspection* discloses an apex beat, usually to the left of the normal site, and much less visible than in health; it is at times invisible. There is a diffused, undulatory, or wave-like character to the pulsation observed over the præcordium (Plate XXII.).

Palpation shows a feeble impulse of irregular and flopping character. The pulse is irregular, small, of little tension, and rapid.

Percussion dulness extends both to the right and left, depending of course on the portion of the heart most involved by the dilatation.

Auscultation.—The heart sounds are feeble, and the rhythm is irregular. From the relative insufficiency of the valves murmurs may arise. When the dilatation is extreme and the force of the heart's muscular contraction feeble, even though valvular lesions exist, no murmur may be heard. In such cases, after rest and the use of cardiac tonics, the contractions of the heart become more forcible and the murmurs again become audible.

PHYSICAL SIGNS OF PERICARDITIS.—When pericarditis is unaccompanied by effusion of serum, the only physical sign is the friction murmur, the "see-saw" sound, which is heard usually at the base of the heart.

If the inflammation goes on, and an effusion of serum into the pericardial sac takes place, the following signs are noted:

Inspection.—Bulging of the præcordium; apex beat not visible or above the normal location.

Palpation.—No apical impulse, or an impulse felt in the third and fourth left intercostal spaces. Fluctuation may be present, though this is a rare sign.

Percussion.—When fluid is present in moderate amount the area of deep cardiac dulness is not increased, but the change from pulmonary resonance to flatness is sudden and marked. When the pericardial sac is distended with exudate, the dulness or flatness begins at the first or second costal cartilage, and extends downward to the sixth rib, and laterally beyond the normal limits of deep cardiac dulness. The outline of the flat area may be pyramidal and extend beyond the normal site of the apex beat. The sense of resistance on percussion is marked.

Often the dulness of pericardial effusion is at first noted in the second left and fifth right intercostal spaces.

Auscultation.—Friction sounds due to rubbing of the pericardial surfaces on one another may be heard, when the fluid is present in only small amount; when large amounts of fluid fill the pericardial sac, friction sounds are usually absent. The heart sounds are heard faintly and apparently at a distance, but when no endocardial murmurs exist they are normal in character.

The difficulty of differentiating between a dilated heart and a pericardial sac filled with fluid is often difficult. The fact that the apex impulse is absent or displaced upward, and not of the undulating character so typical of a dilated heart, in which also the apex beat is usually displaced downward and outward; the shape of the dull area, pyramidal in pericarditis, and square in a dilated heart; the muffled character of the sound in pericarditis, and the accentuated valvular sounds in dilatation; Bamberger's sign, dulness at the angle of scapula, and increased fremitus and bronchial breathing at this point when the patient sits upright, which signs disappear when the patient leans forward, in pericarditis and not in dilated heart, will aid in the differential diagnosis of these conditions.

MITRAL INSUFFICIENCY.—The mitral valve, incompetent, permits regurgitation of blood into the left auricle during systole. This causes an increased amount of blood in the auricle and an increase in the blood pressure of the pulmonary circulation. The auricle becomes primarily dilated and hypertrophied. During each diastole, as a result of the increased amount of blood in the left auricle and of the increased pressure under which this blood is, more blood enters the left ventricle than normal and with greater force: this causes an increase in the capacity of the left ventricle from the yielding of the walls, and then hypertrophy from the endeavor of the left ventricle to empty itself completely during systole.

The increased pressure of the blood in the pulmonary circulation causes hypertrophy and dilatation of the right ventricle—the effort of nature to supply force for the lack of power in the left auricle. When dilatation of the right ventricle ensues, the tricuspid valve becomes incompetent and the blood during systole regurgitates into the right auricle, thence into the ascending and descending venæ cavæ; pulsation of the veins of the neck and pulsating liver follow.

As long as the hypertrophy of the ventricles is sufficient to overcome the valvular deficiency, just so long will no changes be noted in the character of the pulse, and no subjective symptoms will be observed (Plate XXIII., Fig. 1).

Inspection.—Bulging of præcordium at times; apex beat displaced down and to the left; pulsation of the cervical veins and of the liver in extreme cases.

Palpation.—Impulse displaced, but nothing characteristic; very rarely a thrill at apex. Pulse small and of low tension. If the compensation is failing the pulsations of the liver may be felt.

Percussion.—Area of cardiac dulness increased to left, and also to the right of sternum, often an inch or more.

Auscultation.—At the apex, in the mitral area, a soft systolic murmur is heard, transmitted to the left, to the axilla, and at times heard in back along the internal border of left scapula. Though the area of maximum intensity is at the apex, the murmur may be heard along the left edge of the sternum, and also at the base of the heart. The pulmonary second sound is accentuated.

When dilatation of the right heart with the accompanying insufficiency of the tricuspid valve has occurred, a tricuspid systolic murmur may be heard in the tricuspid area; at this stage the pulmonic second sound is weakened.

Mitral Stenosis.—Mitral valve narrowed and the blood flow from left auricle to ventricle obstructed. The first result of the interference with the passage of blood through the mitral orifice is dilatation and hypertrophy of the left auricle, and an increase in the blood pressure in the pulmonary circulation; then hypertrophy and dilatation of the right side of the heart follow, and engorgement of the systemic venous circulation. So little blood enters the left ventricle during the period of diastole that the cavity is not filled, therefore it neither dilates nor hypertrophies, and is not affected by the changes occurring in the other cavities of the heart. There being little blood in the ventricle, little is forced into the aorta with each systole, hence the pulse is small in size (Plate XXIII., Fig. 2).

Inspection.—Bulging of præcordium, especially of sternum and ribs to the right of sternum; apex beat not displaced, usually visible. Epigastric pulsation marked.

Palpation.—The apical impulse is short and snapping, often accompanied by a presystolic thrill. Pulse is small; may be regular if compensation is good, irregular when compensation is failing.

Percussion.—Area of cardiac dulness is increased to right of sternum and upward.

Auscultation.—Presystolic murmur heard at or just within the location of apex beat, over a limited area, rough and harsh in character, not transmitted, and ending suddenly with the first sound of the heart. The pulmonic second sound is usually accentuated. There is often a reduplication of the second sound at the base. At the apex the second sound may be inaudible.

When compensation has failed this lesion may exist, and yet no murmur be heard.

Aortic Insufficiency.—The aortic valve is incompetent, and allows blood to regurgitate into left ventricle during the period of diastole. The first result of this lesion is, that during diastole the cavity of the left ventricle is overdistended with blood, flowing from the auricle through the mitral orifice and from the aorta through the incompetent aortic orifice. The ventricular walls yield to the pressure, and a primary dilatation results; this is followed by hypertrophy of the ventricle in the effort to force the increased amount of blood contained in the cavity into the aorta. It not infrequently happens that from the dilatation of the ventricle there is an incomplete closure of the mitral valve, the so-called relative mitral insufficiency, which acts in a beneficial way by allowing regurgitation and so relieving the pressure in the ventricle during systole. Aortic regurgitation produces a marked effect on the pulse. The more than normal quantity of blood forced into the aorta during each systole causes a sudden and marked filling of the arteries, a quick and full pulse; this as quickly disappears during diastole, when the arteries are emptying themselves in the normal manner, and also backward through the incompetent aortic valve. The pulse seems to collapse; it is the "water-hammer" or Corrigan's pulse, and is characteristic of this lesion (Plate XXIII., Fig. 3).

Inspection.—There may be bulging of the præcordium; the apex beat is dislocated downward and to the left, and the impulse is usually marked and of the heaving character of hypertrophy.

There is marked visible pulsation in the cervical vessels and also in the temporal, brachial, radial, and other arteries. Capillary pulsation in the finger nails is visible at times.

Palpation.—The abnormal location of apex beat and the forcible and heaving character of the impulse are easily made out. There may be a thrill in the aortic area diastolic in time. The pulse, the characteristic Corrigan or "water-hammer," is not marked when compensation fails, or when a marked stenosis of the aortic valve exists with the insufficiency.

Percussion.—Cardiac dulness increased to the left from hypertrophy of the left ventricle.

Auscultation.—Diastolic murmur heard over the aortic area, and transmitted across the sternum and downward along left edge to the tip of the ensiform cartilage. This is usually a soft and blowing murmur coming with or replacing the second sound of the heart.

A systolic aortic murmur is not an uncommon accompaniment of the diastolic murmur; and a mitral systolic murmur is also often heard, the result of the relative mitral insufficiency.

Aortic Stenosis.—The aortic orifice is narrowed, and an obstruction is thus offered to the passage of the blood from the left ventricle into the aorta. This causes an increase of blood pressure in the ventricle during systole; the ventricular walls at first give way to this increase of pressure and a primary dilatation results. This is rapidly compensated by hypertrophy of the left ventricular walls, which takes place as the result of the heart's effort to empty the ventricle of the excess of blood through the narrowed orifice. The pulse is usually small, because of the small amount of blood forced into the aorta with each contraction of the heart, and regular. The tension is usually high (Plate XXIII., Fig. 4).

Inspection.—Apex beat displaced downward and somewhat to the left, visible and somewhat heaving. When compensation fails impulse is wave-like. There is no visible pulsation in any of the peripheral vessels.

Palpation.—Apex beat palpable in sixth space and to left of the mammary line: impulse is slow, regular, and forcible. There is often a systolic thrill in the aortic area. The pulse is regular, small, and of high tension.

Percussion.—Area of cardiac dulness increased to left from hypertrophy and dilatation of the left ventricle.

Auscultation.—In the aortic area a loud systolic murmur is heard, often audible over the whole præcordium and in the vessels of the neck. It may even be heard in the second, third, and fourth left intercostal spaces near the vertebral column. The murmur is systolic in time and usually very harsh in quality; it is transmitted up the vessels of the neck. The second sound is usually faint, it may be absent; or there may be a diastolic murmur replacing the second sound, due to an incompetent condition of the aortic valve.

Murmurs occurring at the same time of the cardiac cycle arising from the same pathological conditions of the valves of the right heart may be heard, and the physical signs resulting from these valvular lesions are much the same as those already enumerated. Lesions of the tricuspid and pulmonary valves are, however, comparatively rare; and the murmurs heard indicating trouble at these orifices arise more commonly from the relative insufficiency of these valves, which is the result of organic lesions of the valves of the left side of the heart, than from structural lesions of these valves themselves.

Tricuspid Regurgitation.—Of the lesions at the tricuspid orifice regurgitation is the more common, and is usually the result of dilatation secondary to mitral disease and consequent stasis of the pulmonary circulation.

Inspection.—Pulsation in epigastrium, in intercostal spaces to right of sternum, and in the vessels of the neck.

Palpation.—Pulsation in epigastrium and to the right of the sternum, and at times the pulsating of the liver may be felt.

Percussion.—Heart dulness increased to the right edge of the sternum or beyond it, and upward, from the hypertrophy and dilatation of the right ventricle and auricle.

Auscultation.—In the tricuspid area, at the end of the sternum and in the fourth and fifth left intercostal spaces near the sternum, a soft blowing systolic murmur is heard; it may be transmitted slightly to the right, but is not heard at the apex. The second sound in the pulmonary area is weak.

Tricuspid Stenosis.—This lesion is usually congenital and is accompanied by dilatation of the right auricle.

Inspection.—Cyanosis is marked, and visible pulsation may be noted to the right of sternum.

Palpation.—The pulsation and at times a presystolic thrill to the right of the sternum may be felt.

Percussion.—Cardiac dulness, from the dilated right auricle, increased to right of sternum.

Auscultation.—Presystolic murmur, harsh in quality, of maximum intensity in tricuspid area, and not transmitted.

PULMONARY REGURGITATION.—The physical signs are those due to the regurgitation of blood into the right ventricle causing it to dilate and hypertrophy. The murmur is like that of aortic insufficiency, diastolic in time and soft in quality; it is heard with maximum intensity in the second left intercostal space, and is transmitted down the sternum. The pulse alone makes it possible to differentiate the murmur from that due to aortic insufficiency.

PULMONARY STENOSIS.—This lesion, usually congenital, causes hypertrophy of the right ventricle, with the usual train of physical signs.

The murmur is systolic in time, harsh in quality, heard loudest in the second left intercostal space and at times all over the præcordium; a thrill may also be detected in the pulmonary area. The sound is not transmitted up the vessels of the neck, like the systolic murmur of aortic stenosis.

FUNCTIONAL MURMURS.—Functional murmurs are those which occur not as the result of any organic valvular lesion, but from functional changes in the heart, vessels, or blood. These murmurs are often spoken of as inorganic, hæmic, or anæmic, from the fancied cause of their production. It is usual to find these murmurs in cases of anæmia, or in the debility following any exhausting disease.

The following characteristics of functional murmurs will aid in differentiating them from organic murmurs. They are always systolic in time, and are as a rule heard loudest in the pulmonary area, though they may be heard at the apex, and in the aortic and tricuspid areas. The murmur is soft and blowing, and usually louder when the patient is in the recumbent position. There is no transmission, and usually no hypertrophy or dilatation. The second sound in anæmic murmurs is usually somewhat accentuated.

There may be vascular murmurs associated with the functional cardiac murmurs; the most common is that heard in cases of anæmia in the neck over the jugular veins: the so-called "venous hum," or "bruit du diable." This sound may be produced by pressure on the veins with the bell of the stethoscope in persons who are in perfect health.

ANEURISM OF THE THORACIC AORTA.—Aneurism of the arch of the aorta may be fusiform or sacculated, and is usually secondary to syphilis, alcohol, gout, or great muscular strain. The physical signs depend on the location of the aneurismal tumor, the presence of the tumor, and the pressure the tumor exerts on the surrounding structures.

The physical signs due to the tumor itself are pulsation, usually expansile, thrill, dulness, and murmur. It is quite possible, however, for an aneurism to exist without giving any physical signs.

Inspection.—If the aneurism is of the ascending arch, there is often bulging in the first and second right intercostal spaces, and here also a pulsation may be visible. When the aneurism is located in the transverse arch of the aorta, the manubrium is pushed forward and the tumor shows itself in this location; the pulsation is noticed here, and also in the suprasternal notch. Aneurism of the descending arch is usually accompanied by a tumor in the second left intercostal space in front, or in the third, fourth and fifth intercostal spaces of the left interscapular region.

The use of the *x*-ray in examining patients in whom aneurism is suspected is of great assistance. By means of the fluoroscope the presence of a dark and pulsating shadow, larger than that seen in examining the normal heart, is made out, often when no other physical signs of aneurism can be detected. It is most important to make use of this means of examination in all cases of suspected aneurism.

On inspection also the apex beat of the heart may be found dislocated downward and to the left.

Palpation.—At the point of bulging, pulsation, usually expansile in character, may be noted, and a systolic thrill may sometimes be felt. When the aneurism is of the transverse or upper part of the descending aorta, tracheal tugging may be present. To obtain this sign, the head of the patient, who sits, should be supported against the body of the observer, who stands behind the patient; the observer then places the first or second finger of each hand on either side of the cricoid cartilage. The head should be slightly bent forward and the patient told to stop breathing. With each systole of the heart the fingers appreciate a distinct tug transmitted to them through the trachea and cricoid cartilage, which are dragged down by the expansion of the aneurism upon the left bronchus.

A difference in the character, time, and force of the pulse in the two wrists may be noted; the vessels receiving their blood supply from the aneurismal sac having a weak and retarded pulse wave.

Percussion.—There is dulness over the location of the tumor. When there is no visible tumor, dulness in the second right intercostal space or in the left interscapular region near the vertebral column is suggestive of aneurism.

Auscultatory percussion is of much value in diagnosis of the presence of a tumor in the mediastinum.

The heart dulness is usually not increased unless there is valvular disease, usually incompetence of the aortic orifice, associated with the aneurism.

Auscultation.—There may be a systolic or a systolic and diastolic murmur heard over the tumor. In a large number of cases, however, no murmur can be made out. The second aortic sound is accentuated; at times the closure of the valves is so forcible that the palpating hand can feel the shock.

Pressure Symptoms.—An aneurism may exist and give no physical signs, yet characteristic pressure symptoms may be present. The symptoms caused by pressure often coexist with the physical signs due to the tumor, and depend largely on the location of the tumor and the structures upon which the pressure is exerted.

Pain is usually a constant symptom, sharp and stabbing in character, and may occur in paroxysms. The pain may be due to the erosion of bone, sternum, or vertebræ; may be anginal in nature, or result from pressure on the nerves, and shoot down the arm to the fingers or along the intercostal spaces.

Pressure on trachea and bronchi gives rise to cough, bronchorrhœa, and hemorrhage, at times slight and apparently from the lungs, at times profuse and fatal from ulceration of the aneurismal sac and rupture into the trachea or bronchus.

Pressure on vena cava, if on superior, causes cyanosis, enlargement of the veins, and œdema of the head, neck, and arms, usually the right; if on the inferior, there may be œdema of the thorax and feet.

Pressure on the œsophagus causes dysphagia, and the aneurism at times ruptures into the œsophagus. Pressure on the recurrent laryngeal nerves produces a dry metallic cough and aphonia. The paralysis of the abductor muscles of the larynx is easily made out by laryngoscopic examination. The left vocal cord is the one most frequently paralyzed. Pressure on the sympathetic nerves may produce contraction of one pupil, and flushing and sweating of one side of the face. Pressure on the brachial plexus, sternum, and vertebræ produces pain.

William K. Draper.

CHESTNUT.—*Castanea.* "The leaves of *Castanea dentata* (Marshall) Borckh. (fam. *Fagaceæ*), collected in September or October, while still green" (U. S. P.). This is one of the largest and most valuable of our timber trees, growing rather rapidly, and producing an abundance of straight-grained, rather coarse, but very durable wood. The ripe fruit or nut is well known. The official description is as follows: "From six to ten inches (15 to 25 cm.) long, about two inches (5 cm.) wide, petiolate, oblong-lanceolate, acuminate, mucronate, feather-veined, sinuate-serrate, smooth, odor slight, taste somewhat astringent." Doubtless other species of chestnut leaves have the same composition and might with equal propriety be used. Nothing peculiar has been found among the constituents of chestnut leaves; nine per cent. of tannin, *resin*, and a number of mineral compounds in the ash, are the principal things observed.

Their use is entirely empirical. The leaves for a good many years have had a popular reputation for the relief of whooping-cough, and within the last ten or fifteen years have been considerably used in its treatment by physicians; their value for this purpose is, to say the least, uncertain. Sometimes there appears to be a marked decrease in the number and severity of the coughing spells; at others no effect is produced. They are not put to any other use. The fluid extract is official, the dose being 2 to 8 c.c. (fl. ʒ ss.–ij.).

W. P. Bolles.

CHEWSTICK.—The stems of *Gouania Domingensis* (fam. *Rhamnaceæ*). This is a beautiful woody climber, growing both wild and cultivated in the West Indies, and other parts of tropical America, whose stems are used there as tooth-brush and powder combined. These stems are very tough and fibrous, and when cut in shortish pieces the ends are chewed until a rude, stiff brush is formed, with which the teeth are rubbed; a pleasant saponaceous froth of an aromatic bitter taste is formed in the operation, and the teeth are said to be whitened and the gums hardened by it. A tincture and powder are proposed as dental remedies. Internally, it acts as a mild aromatic bitter, and is used in its home as a constituent of small beers. Manufacturing houses offer a fluid extract, the dose of which is 4 to 8 c.c. (fl. ʒ i.–ij.).

Henry H. Rusby.

CHEYNE-STOKES RESPIRATORY PHENOMENON. See *Dyspnœa* and *Respiration.*

CHICAGO, ILL.—A city of a million and a half or more inhabitants, situated upon the west shore of Lake Michigan. Its climate, although a very variable one and subject to sudden changes, with excessive heat or cold and increased humidity, is not an unwholesome one; and the death rate from consumption along the west shore of the lake is less than farther inland. According to Dr. John A. Robinson[*] the physiological effect of the lake climate is to promote physical activity and mental vigor, and to increase bodily nutrition. "Persons," he says, "who have been predisposed to pulmonary tuberculosis have enjoyed robust health in this climate so long as they have avoided its bad features and observed other precautions." The favorable features of the climate, as Dr. Robinson gives them, are: first, air in motion, the winds sweeping down into the dark corners of the streets and alleys, and whirling the filth into the highways where the rain and sunshine disinfect it; these winds act as great atmospheric purifiers. Second, the lake purifies the air as it blows from its surface toward the land. Third, the large amount of sunshine. "Observations for several years," continues Dr. Robinson, "prove that the monthly mean of cloudy days is about ten a month; which means that the sunshine is present about two-thirds of the time." From the accompanying climatic table it will be seen also that the number of clear and fair days is two hundred and fifty-seven a year.

CLIMATE OF CHICAGO, ILL.—LATITUDE, 41° 52′; LONGITUDE, 87° 38′. PERIOD OF OBSERVATION, THIRTEEN YEARS.

Data.	January.	April.	July.	Year.
Temperature (Fahr.)—				
Average or normal	25.8°	45.4°	72.3°	48.8°
Average daily range	14.9	14.3	14.3	
Mean of warmest	32.6	54	80.1	
Mean of coldest	17.7	39.7	65.8	
Highest or maximum	65	83	99	
Lowest or minimum	−20	17	50	
Humidity—				
Average or relative	76%	66.5%	70.6%	70.8%
Precipitation				
Average rainfall in inches	2.04	3.65	3.96	37.58
Wind—				
Prevailing direction	S.W.	N.	S.W.	S.W.
Average hourly velocity in miles	9	9.5	7.1	8.4
Weather				
Average number of clear days	7.8	8.1	12.9	108.5
Average number of fair days	12.9	12.2	12.5	148.6
Average number of clear and fair days	20.7	20.3	25.4	257.1

The authority above quoted does not think the Chicago climate contraindicates the establishment of a sanatorium, in the vicinity, for the treatment of curable cases of consumption. "At any rate," he says, "the climate in the lake region affords as good an opportunity as the climates of England and New England." For a statistical account of the Chicago climate one is referred to "The Climate of Chicago," by Professor Hazen, 1893, of the Weather Bureau, published by the United States Government.

Edward O. Otis.

CHICHANCANAB.—Yucatan, Mexico. The water of this lake is perfectly clear and very bitter in taste. It deposits crystals similar in appearance to those of magnesium sulphate.

N. J. Ponce de León.

CHICHIMEQUILLAS.—Querétaro, Mexico. Nothing much is known of these waters. The laity recommends them in cases of rheumatism, leprosy, and disorders of menstruation.

N. J. Ponce de León.

CHICHIPICO.—Puebla, Mexico. This is a lukewarm sulphureted calcic water. Although there are no bathing facilities at this spring, many people take the baths, as they are highly recommended by local physicians, for the treatment of rheumatism and nervous disorders.

N. J. Ponce de León.

CHICKENPOX.—(Synonyms: Varicella, Crystalli, Swinepox; Fr., *La Varicelle;* Ger., *Wasserpocken.*) Chickenpox is an acute, specific, infectious fever, characterized by successive crops of vesicles distributed over the entire surface of the body, which disappear, in from four to seven days, by desiccation. It is the mildest and least important of the eruptive fevers.

The belief, formerly generally entertained by the profession, that varicella is not an independent affection but a modified variola, is now abandoned, save by a few clinicians who follow the teaching of Kaposi and the Vienna school. The proof of the non-identity of the two diseases is overwhelming.

Varicella, like the other members of the exanthematic group, is due to a specific virus, or poison, the nature of which is unknown. It is pre-eminently a disease of early life. It affects babes at the breast, attains its maximum frequency about the fifth year, and is rarely met with after the tenth year of age. It rarely occurs a second time in the same individual. Adults enjoy special immunity from the disease, even when unprotected by an attack in childhood.

Sporadic cases of chickenpox are sometimes observed, but it usually prevails as an epidemic. It is highly contagious, and few children who are susceptible to its influence escape when exposed. Many authors affirm that inoculation with the contents of the vesicles yields negative results, but Steiner and others have repeatedly reproduced the disease in this way. The period of incubation in these experimental cases is about eight days, but when the disease is transmitted in the ordinary manner it is longer and more variable, running from ten to seventeen days.

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[*] North American Practitioner, Chicago, 1897, ix., pp. 296–298, "Chicago as a Health Resort."

Prodromal symptoms are not infrequently wholly absent, the appearance of the eruption giving the first indication that the child is ailing. When present, they rarely last longer than twenty-four hours, and are such as usher in mild febrile attacks, namely, anorexia, lassitude, general bodily discomfort, chilliness, and slight elevation of temperature.

The initial fever is mild, seldom measuring more than 101° F., and the constitutional disturbances are correspondingly slight, but in exceptional cases they may be as severe as those which commonly attend mild attacks of the other eruptive diseases. The eruption follows promptly on the first increase in temperature, and in a few hours attains its full development. Small hyperæmic patches resembling roseola spots first appear and are speedily followed by vesicles. When fully formed, the eruption consists of perfectly transparent vesicles, more or less abundantly scattered over the body, globular or ovoid in form, and varying in size from a pinhead to a split pea, or even larger. They are unicellular in structure, collapse when pricked, and leave behind no swelling or elevation of the skin. A distinct areola may or may not be present.

The wall of the vesicle, formed by the outer layer of the epidermis, is very thin and easily broken.

When the eruption is abundant the body, as well described by Dr. Gregory, presents the appearance of having been exposed to a momentary shower of boiling water, each drop of which has produced a small blister.

The eruption appears first upon the trunk, and spreads irregularly over the entire body. It is most abundant upon the back and breast, and least so upon the face, where it is usually limited to the forehead. The scalp nearly always exhibits a full crop of eruptions, which, protected by the hair, maintains its physical integrity longer than in any other location, and thus renders valuable aid in diagnosis. The eruption is never confluent.

The occurrence of two, three, or more successive crops of eruption, each running an independent course, constitutes a striking and unique feature of varicella. Between the vesicles first formed new roseola spots appear, and soon ripen into fully developed vesicles. Thus, newly formed vesicles may be seen side by side with others in all stages of development, even to advanced desiccation. The irregularity in the course and development of the eruption is an important point in the diagnosis of the disease.

The mucous membranes are often implicated. The tongue, buccal membrane, and the mucous surfaces of the genital organs, especially in girls, are favorite sites for the formation of vesicles. In these locations the vesicles soon lose their epithelial covering, and leave small, round, superficial ulcers resembling the ulcers of herpetic stomatitis.

If unbroken by accident or by the scratching of the child to relieve the itching so generally present, the vesicles remain until the third day without change, when their contents become cloudy and desiccation begins.

At this stage a few scattered pustules may be observed, but these are purely accidental and not essential features of the disease. The vesicles begin to dry up in the centre and form thin, brownish-yellow crusts, which soon become detached. Faint red spots remain, which pass away in a few days, and carry with them every trace of the eruption; but very exceptionally depressed, slightly pitted cicatrices permanently mark the seat of a few of the vesicles.

Mr. Hutchinson has called attention to the gangrenous ulcers which sometimes, though rarely, complicate chickenpox in feeble, ill-nourished infants. In these cases a greater or less number of vesicles, instead of pursuing the ordinary benign course, become gangrenous, increase in size, and form black scabs of one-half to one inch in diameter, surrounded by dusky red areolæ. The ulcers heal slowly. In fact this condition may result fatally in infants whose constitutions are depraved by inherited taints or bad surroundings. It is not peculiar to varicella and is described on other pages of the HANDBOOK under the name of Varicella Gangrænosa.

The varieties of chickenpox described by authors under the names of *Varicella lenticularis*, *Varicella conoides*, and *Varicella globata*, based on the various shapes assumed by the eruption, may be wholly ignored, since in every well-marked case vesicles answering all of these descriptions are abundantly found. In fact this variability in size and form of the typical varicellar eruption is a characteristic feature of the disease. The prognosis is always favorable.

Erysipelas is the most serious, though a rare complication. Holt has met with three fatal cases.

Henoch and others have reported cases of nephritis occurring both as complications and as sequels. Varicella is not infrequently complicated by other infectious fevers. The combination of scarlatina and varicella has been often observed.

Varicella derives its chief importance from the liability of inexperienced or careless diagnosticians to mistake it for smallpox, or *vice versâ*.

In variola, or well-marked varioloid, the physiognomy is so distinctive as almost to preclude the possibility of error. But in exceptional cases of varioloid the constitutional symptoms are so mild and the eruption so rudimentary and irregular that a careless examination will not suffice to distinguish them from the graver forms of varicella.

For two years or more an unusually mild form of variola has prevailed extensively throughout the country, especially in the South and middle West. The mortality has been almost *nil.* In 2,819 cases recorded in Ohio up to January, 1900, the death rate was 1.4 per cent. During most of the time varicella has been epidemic in a part of the same territory, which with the exceedingly mild type of variola has given rise to much confusion and many mistakes in diagnosis.

Time will always clear up the diagnosis, but in the meanwhile the reputation of the physician and the safety of the community may be seriously compromised.

The absence of prodromal manifestations, the short initial fever, the rapidity and irregularity with which the eruption spreads over the body, the globular, non-umbilicated, transparent, unicellular vesicles, the absence of a distinct pustular stage, and the successive crops of eruption, which show roseola spots, vesicles, and crusts in close proximity, will rarely give room to hesitate in the presence of chickenpox.

While any case of varicella may present an occasional vesicle slightly umbilicated or with purulent contents, due to accidental causes, the fact that this appearance is only exhibited by a few scattered vesicles, and is not the predominating character of the eruption, will suffice to establish the diagnosis.

It is well to bear in mind that a vesicular eruption which occurs in a child over ten or twelve years of age, and especially in an adult, is open to grave suspicion. The writer cannot, however, agree with those authors, by no means few in number, who maintain that varicella never occurs in the adult. He can recall three cases in adults, all females, which have come under his observation.

Varicella is a self-limited disease and needs but little treatment.

Light diet, cooling drinks, a gentle aperient, and confinement within doors while the fever lasts, is all that will ordinarily be required. To prevent the infection of other children isolation should be maintained until the crusts have fallen. *W. J. Conklin.*

CHICK'S SPRINGS.—Greenville County, South Carolina.

POST-OFFICE.—Greenville. Hotel and cottages.

ACCESS.—Viâ Atlanta and Charlotte Air-Line (Southern

Railway system), to Taylor's Station, 10 miles from Greenville, thence 1 mile to springs.

Chick's Springs are located in a broken, rugged country, about 1,200 feet above the sea level. Paris Mountain, a spur of the Blue Ridge, is only three or four miles distant. The climate of this region is very salubrious and well adapted for pulmonary cases during the winter months. The air is dry, and clear weather with invigorating breezes the rule. The resort has had a wide reputation in the South for many years, but owing to the destruction of the hotel by fire it has not been open to the public until two or three years since, when the present owner built a small hotel and several cottages. A large, new hotel is projected, which, with other improvements, will bring the place up to its old standard of excellence. The springs are two in number, known as the "Iron" and the "Sulphur" Springs, and are about one hundred and fifty feet apart. The following analysis by Dr. Charles U. Shepherd, of Charleston, was sent to us by Mr. Julius C. Smith, of Greenville:

ONE UNITED STATES GALLON CONTAINS:

Solids.	Grains.
Calcium sulphate	32.57
Magnesium sulphate	.63
Sodium sulphate	2.37
Sodium silicate	3.69
Potassium silicate	.31
Silica	.50
Iron oxide	.41
Total	40.48

Carbonic acid gas present in appreciable quantities.

These waters have been found of great advantage in cases of atonic dyspepsia accompanied by hepatic congestion. They are also useful auxiliaries in Bright's disease of the kidneys. *James K. Crook.*

CHICORY.—*Cichorium.* The root of *Cichorium Intybus* L. (fam. *Cichoriaceæ*). A perennial, milky-juiced, European herb, with dandelion-like leaves and tall, sparsely branching stems, bearing large, delicate, bright blue flowerheads. It is very abundantly naturalized in this country, along roadsides, and is also extensively cultivated both here and abroad. The root is fleshy and branched, very much like that of dandelion when dry, but rather larger, and deficient in regard to the bright yellow woody ring so distinctly seen in the cross section of dandelion. It is grayish brown externally, whitish within, generally odorless, and but slightly bitter. The cultivated root is larger and darker than the wild. It occurs in commerce mostly cut into halves and quarters of transverse sections, and is heavily wrinkled in drying. The leaves, which are somewhat employed as a salad, are irregularly pinnatified, with a large terminal and small lateral segments. They resemble lettuce in taste, but are more bitter.

The roasted root is very extensively used as an adulterant of, or addition to, or substitute for coffee, and this use is steadily increasing. In some European countries, especially England, it is generally assumed that the customer desires the addition of chicory unless he directs otherwise. To the natural taste, it imparts a bitter and nauseous flavor to the beverage, but this, by custom, becomes tolerable or even agreeable.

Chicory is scarcely entitled to rank as a medicine, although it is laxative and about similar to dandelion in its effects. The root contains *inulin*, like many others in the order, *bitter extractive*, and *sugar*. The flowers contain a peculiar glucoside. *Henry H. Rusby.*

CHIGOE.—SYNONYMS.—Besides the classical terms *Pulex penetrans*, *Dermatophilus*, *Rhynchoprion penetrans*, and *Sarcopsylla penetrans*, this troublesome tropical parasite is known by the following names: aagrini, atten, bicho, bichos dos pes, chego, chegoe, chegre, chica, chico, chicque, chigga, chigger, chiggre, chigo, chigoe, chigua, chique, ckicke, earth-flea, jatecuba, jigger, migor, nigua, pico, picque, pigne, pigue, pique, punque, sand-flea, sandfloh, seccec, sico, sike, sikka, siko, tchike, tom, ton, tschicke, tschik, tschike, tû, tunga, tungay, xique.

ETYMOLOGY.—*Chigoe* is supposed to be derived from the Spanish *chiquito*, small.

For natural history, classification, anatomy, etc., see article *Insects.*

GEOGRAPHICAL DISTRIBUTION.—The chigoe is confined exclusively to the tropics, and is probably indigenous to South America. It is most prevalent in the West Indies, and Central and tropical America, its bounds being about 30° of latitude North and South. Within these limits it is certainly very common indeed, and for its size is the most troublesome of all the tropical pests. Till about twenty-five years ago it had never been known out of the Western hemisphere, save for a stray case imported into Europe from South America or the West Indies (one such case is elaborately reported by Laboulbène); but in 1872 or 1873 it was found in tropical Africa, and within the last decade it is said to have reached South China.

Probably it will be found all over the tropics. It is most abundant in the dry sandy soil, and in the parts near the sea; also in pens, stables, and in the dust, ashes, etc., of neglected, unswept houses. Negroes are chiefly affected, and those who work or go about with bare feet, and are not accustomed to hygienic surroundings and conditions. Europeans and newcomers suffer the most, but probably because the older residents know what trouble these little pests can give, and have learnt from experience to appreciate the first signs of the presence of the parasite. Women and children with their thinner and more delicate skin suffer very much. Soldiers have been attacked by these tiny parasites and have been discomfited if not routed by them. "It is stated that as early as 1538 a division of Spanish troops was disabled from marching by swarms of the parasite settling in their feet. In recent times the French troops under Bazaine, in the Mexican expedition, had the same unfortunate experience" (Hirsch).

Short Description.—The chigoe is a parasite of the "flea" tribe; it is smaller than the flea, but has a larger head. It attacks birds, warm-blooded animals both wild and domestic, as well as the human subject. The male and immature female are both free parasites, obtaining their board and lodging wherever they can, but on impregnation the female seeks a host. It is the impregnated female that causes all the trouble, and it is to her alone that we refer in the present article. With its head the chigoe bores into the skin, going obliquely through the epidermis; it then enters between the epidermis and dermis, and burrows down into the latter, but probably never goes deeper; from the capillaries of this region it obtains its food supply.

Parts Affected.—All portions of the body are liable to attack, but the chigoe exhibits a decided preference for the feet. These are nearly always involved, especially under and around the nails, and in the digito-plantar fold. The insertion of the tendo Achillis is another favorite place. The dorsum of the foot is very seldom involved. Next to the feet, the scrotum, prepuce, corona glandis, axilla, arm, forearm, palm of hand, lower eyelid, cheek, neck, elbow, and knee are places of predilection; and as the feet and genitals are oftenest attacked, the question has been raised as to how far the chigoe is attracted by the odor of those parts, especially in the uncleanly. As a rule only one or a few chigoes are found, but Bonnett reports a case in which he found no fewer than three hundred in one person. It has also been stated that the chigoe likes to effect an entrance either near to another chigoe, or into the very spot which another chigoe has previously occupied; the neighborhood of an ulcer produced by her comrades is also attractive to the chigoe.

CLINICAL COURSE AND SYMPTOMS.—Three stages have been described, but ordinarily only the first two are observed; and if proper care be bestowed the trouble is limited to the first stage.

1. *Period of Invasion.*—This lasts for from twenty-four to thirty-six hours, and is marked by itching and tick-

ling, due to the perforation of the skin. The sensation, which at first is not very definitely localized and sometimes is a little way from the actual seat of the trouble, is rather pleasant than otherwise; and many people have been known to keep the insect for a day or two before extracting it. The pain or discomfort is intermittent; but as the sac with the eggs increases in size it presses on the neighboring tissues and gives rise to a slight pain, which later becomes dull and throbbing and increases in intensity. At first there is nothing to be seen, but as the sac grows there can be observed a small spot, black or dark blue in color, and somewhat deeply set in the skin which at this stage is hardly raised. If the trouble be near a nail (as it is very apt to be) inflammation will soon follow unless the sac be carefully extracted. In delicate people even one chigoe will cause lameness and hinder walking.

2. *Period of Inflammation.*—If the insect be allowed to remain in the tissues, or the sac be ruptured and some of the eggs remain, inflammation ensues, the intensity of which depends on the thickness of the skin and the richness of its vascular and nerve supply. If the skin is thick, there are pain, very little heat or redness, and little or no swelling; in other cases there are considerable pain, heat, and redness, and a serous fluid is present. If there are several parasites with well-developed sacs, the degree of inflammation is very great, and there is the possibility of further trouble. This second stage lasts for four or five days, sometimes longer; the inflammation only ceasing on the extraction of the chigoe.

3. *Period of Ulceration.*—If the part be still neglected and the inflammation remain unchecked, a large ulceration occurs; the vessels may become obliterated, and gangrene is a possible result. Ulceration is very common when several chigoes are present in close proximity; and the union of several small ulcers gives a very ugly sore. The ulcer is characterized by red, scalloped edges, grayish base, and thin fetid pus which may separate the epidermis from the dermis. These ulcers are apt to spread along the surface, and in very severe cases the skin is destroyed, subjacent structures are denuded, tendons laid bare, phalanges may be necrosed, and toes drop off. This is exceedingly rare, and we believe that the severe symptoms attributed to this stage have been exaggerated.

PROPHYLAXIS consists in personal cleanliness, particularly in constant bathing of the feet. Avoid sleeping on the ground, and do not go barefooted. Keep socks and bedroom slippers off the floor when not in use. See that rooms are swept and floors sprinkled. Some people use a pungent essential oil to keep away the insect, the natives employing an infusion of tobacco leaves for this purpose.

TREATMENT.—There is but one method that can be recommended, and that is careful extraction of the sac at the earliest possible moment. On the first itching sensation a search should be instituted for the insect, which when found should be at once dislodged. This is best accomplished with a sharp needle, which should be sterilized by passing through a flame, and then carefully inserted in the opening made by the chigoe, and passed round the sac, separating it from the tissues, and when thus loosened it can be extruded. Great care must be taken to avoid breaking the sac and scattering the eggs. If unfortunately this should occur, wash out the débris with water (sterile if possible) or a mild solution of bichloride of mercury. If the skin is very thick an incision may be necessary. The negresses are skilful in "echiquage" (as extraction of a chigoe is termed), but it is very necessary to see that they employ a surgically clean needle. If a dressing is considered necessary, a three or four per cent. solution of carbolic is as good as any. If the wound is large and intractable to ordinary treatment, you may have to curette and treat as any other fresh wound. Care must be taken to prevent the entrance of any pathogenic bacteria. Inflammation is treated in the usual way. If ulceration has occurred, chloroform liniment or mercurial ointment can be employed; and in the very worst cases, and those badly neglected, amputation may be necessary. *R. J. E. Scott.*

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CHILBLAIN. See *Dermatitis calorica.*

CHILDHOOD.—In the arbitrary division of life employed for purposes of description or discussion, childhood includes the period from the end of the second year to puberty. The material for our consideration, therefore, includes all the phenomena that belong to the human organism in its progress from the conditions prevailing at the end of the second year of life to those of maturity.

Naturally at the outset of this period the organism, both in conformation and in function, corresponds closely to the infantile type, yet it has progressed sufficiently far to exhibit in some degree nearly all the powers that belong to the fully developed organism. No essentially new powers are developed until the concluding years of the period introduce the changes incident to puberty.

At the end of the second year the body still maintains many of the infantile characteristics. The head is large in proportion to the size of the body, its circumference being about nineteen inches; the trunk is large in proportion to the extremities, the general outlines are full and round. The child at this age, however, has attained such a degree of muscular co-ordination that he is able to stand, walk, or run, and to use the hands freely. The special senses are all awakened to a degree, and he has acquired a certain small store of experience, is constantly adding to that store, and in a feeble way reasoning upon the results of it. The same development from the condition at birth, which is so especially notable in the case of the brain and nervous system, is also to be observed in the other organs of the body. The lachrymal glands are very active, the mouth has filled with teeth, the salivary glands have assumed their functions, the stomach and intestines are possessed of increased digestive power, and the eliminative functions of the kidneys are more in evidence. A more detailed consideration of some of the anatomical and physiological peculiarities of childhood will be in order.

The Skin.—The superficial area of the body in childhood relatively to the size and weight of the body is much greater than in adult life. Changes in the condition of the skin have, therefore, a relatively greater influence in the earlier years. Children react to cold or hot applications to the surface of the body very quickly and markedly. Hydropathic treatment must therefore be carried out very carefully, and the length of exposure to either heat or cold regulated by the effect upon the general condition. Under proper regulation we can expect more marked and lasting effects from such measures in children in an inverse relation to their age. Thus simple sponging of the surface of the body with cold water or the application of a cold pack may be quite sufficient in a child to produce an effect which in an adult would require a prolonged cold bath.

The sensitiveness of the child to sudden changes of the temperature of the body should not be lost sight of in considering the questions of hygiene. The surface of the body should, as a rule, be protected, even in summer. The exposure of the neck and chest, arms and legs of a delicate child—often resorted to by mothers in the belief that it will "harden" the child—is much more likely to result in weakening it or even producing definite and severe illness.

Except in the hottest part of summer flannel or wool should be worn next the skin, and whenever it is dispensed with, particular care should be exercised to prevent sudden chilling of the surface of the body. Proper care of the surface of the body will protect a child from many of the attacks of inflammation of the respiratory or alimentary tract to which childhood is so susceptible.

On the other hand, daily bathing should be as systematically carried out in childhood as in infant or adult life. No specific rule can be given for the temperature or duration of the daily bath. These must be regulated according to age and constitutional vigor. A bath that leaves a child blue, cold, and shivering for some time after it must be harmful, but such results are unnecessary. Either by lessening the duration of the bath or by raising the temperature of the water, they may not only be avoided, but in their stead we can secure a healthy reaction which will leave the skin warm and glowing and the child stimulated and strengthened. No other one measure is so potent in increasing the vitality of weakly children and enabling them to avoid the constant recurrence of colds as systematic bathing with water at the lowest temperature compatible with a proper reaction. As a rule, the gradual reduction of the temperature of the bath is not only feasible, but advisable. The rate of reduction must be regulated by the effects produced.

Not only is the skin area relatively greater in childhood, but the skin itself is more delicate and more readily affected by any application. The use of external remedies, either in the form of lotions, ointments, dressings, or local applications, must be carefully watched and limited to small areas. Local irritants or caustics are to be employed with care. Blisters, burns, and severe ulcerations are readily produced by incautious applications to the skin; even grave constitutional effects may be produced by the external use of such readily absorbable substances as carbolic acid and its allies.

The skin in childhood readily reflects disturbances of other parts of the body, especially the gastro-intestinal tract. Eruptions dependent upon disturbances of the stomach or bowels are frequently seen, and the dietetic treatment of skin diseases is seemingly much more potent in childhood than in adult years.

The Bones.—At the beginning of childhood the bones are still very cartilaginous and soft. Ossification progresses very slowly till puberty is reached. The fontanels are closed, but the bones of the skull are still relatively thin and soft, and the sutures remain open for many years. The spine of a child is remarkably soft and flexible, because of the limited ossification of the vertebræ. At the end of the second year it still presents the nearly perpendicular column characteristic of infancy. During childhood the S-like antero-posterior curvature characteristic of adult life is developed. Owing to the softness of the vertebræ and the laxity of the ligaments, the conformation of the spine during childhood is readily influenced by the attitudes of the body, and much more attention than is usually given should be paid to the postures and carriage of the child.

The thorax of the child gradually changes its form from the change in the curvature of the spine and attendant changes in the direction of the ribs. The ribs, as age increases, are directed more obliquely downward. The thorax becomes relatively broader above than below, a reversal of the conditions found in infancy.

The pelvis in childhood gradually enlarges so as to be more capacious, and receives more of the abdominal viscera, thus diminishing the prominence of the abdomen so notable in early life. There is practically no difference in the pelves of the two sexes until the changes of puberty introduce the special characters of the sexes.

The bones of the extremities in childhood show the division into diaphyses and epiphyses. There is active growth at the junction of the shaft and epiphysis; the bones are still soft and easily affected by pressure. In consequence of these conditions deformities are easily produced, and are also, as a rule, readily amenable to proper mechanical treatment.

The Teeth.—At the close of the second year, or within the following sixth months, the eruption of temporary teeth, twenty in number, is completed. At this time the child has not only the temporary teeth, but also the calcified crowns of all the permanent teeth except the second and third molars. The crowns of the second molars begin to be calcified during the fourth or the fifth year, but the third molars, or wisdom teeth, are not calcified till puberty. At the end of the fifth, or the beginning of the sixth year, therefore, the jaws contain not only the temporary teeth, but all the permanent excepting the wisdom teeth. At this period there occurs a marked development of the jaws in the horizontal plane, in order to accommodate the permanent molars, which make their appearance posteriorly to the temporary molars. The permanent teeth are cut in the following order:

	Year.
Molar, first	Sixth.
Incisor, central	Seventh.
Incisor, lateral	Eighth.
Bicuspid, anterior	Ninth.
Bicuspid, posterior	Tenth.
Canines	Eleventh to twelfth.
Molars, second	Twelfth to thirteenth.
Molars, third	Seventeenth to twenty-fifth.

Owing to this eruption of the permanent teeth, the care of the teeth in childhood is of especial importance. Undoubtedly much of the common early decay of the permanent teeth is to be attributed to lack of care of the mouth during the critical period of their eruption. Usually as soon as the proper care is given, the decay ceases, and the condition of the teeth remains good for many years. Good teeth are so necessary to the preparation of food for digestion that every effort made for their preservation is a step toward improved digestion and assimilation.

The Alimentary Tract.—Anatomically the child possesses practically the digestive apparatus of an adult. That is, he has teeth, salivary glands, œsophagus, stomach, small intestine (relatively longer than in an adult), large intestine, rectum, liver, gall bladder, and pancreas. There are certain slight anatomical differences from the adult type. The stomach occupies still a somewhat more vertical position, and the cardiac sphincter is poorly developed. The liver is relatively large. The small intestine is relatively long. Little of the intestines is found in the pelvis owing to its small size. The sigmoid flexure is remarkably long and may be found in almost any part of the abdomen. These differences, however, are not sufficient to account for any marked difference in the digestion of this period from that of adult life. Functionally also the several parts of the digestive apparatus are active. Still there is a notable deficiency in the digestive powers in the earlier years of childhood. The several digestive fluids have not the power that they acquire in later life, and undoubtedly much harm is done children by allowing them from their earliest years the general diet of their parents. The transition from the milk diet of the first two years to a general diet should be slowly and cautiously made.

The rapidity of bodily growth and the unceasing activity of children render the metabolism of the organism much more rapid than in adult life. A child therefore requires an amount of food greatly out of proportion to its size and weight. According to the estimates, partly based on experiment, partly arbitrarily assumed, of Atwater and Bryant,[1] a child from 3 to 5 years old requires 0.4 the food of a man; a child from 6 to 9 years old requires 0.5 the food of a man, and a child from 10 to 13 years old, 0.6 the food of a man.

According to Edward Smith, the growing child, in proportion to its weight, requires about three times as much carbonaceous food as the adult and six times as much animal food. Evidently if these demands are to be met, care will be required in both the selection and the preparation of the food during this period of life. In the absence of such care disorders of stomach and intestines naturally result. Probably the great majority of children, especially those of school age, suffer in greater or less degree from indigestion and constipation, or diarrhœa. In the earlier years the parents require instruction as to the proper care of their children's diet; later the children themselves require instruction and training in these fundamental matters of health. It is impossible in this article to go minutely into the diet of children of various ages. Thompson's "Practical Dietetics" contains a store of information on the subject.

The Kidneys.—In keeping with the generally more active metabolism of the child, it is commonly agreed that children void relatively more urine than adults and that the proportion of urea is higher. The most extensive observations the writer has been able to find are those of F. S. Churchill,[2] made upon the children of the Half-Orphan Asylum of Chicago. These observations are so complete as to make them especially valuable, and they are therefore reproduced in full:

Urine in Childhood—F. S. Churchill.

Age.	Weight in kilogram.	Sex.	Total specimens.	Amount in cubic centimetres.	Specific gravity.	Urea, per cent.	Total urea, grams.	Chlorides, grams.	Phosphates, grams.	Sulphates.	Amount of urine to 1 kgm. body weight.	Urea to 1 kgm. body weight.
3 years	16.8	2 males.	5	358	1024.0	2.2	7.87	12.50	12.00	1.08	21.3	0.468
4 "	16.9	7 males. 4 females.	31	299	1027.1	2.9	8.67	11.17	9.22	1.41	17.6	.513
5 "	16.8	1 male. 7 females.	17	392	1024.5	2.6	10.19	10.37	8.89	1.13	23.3	.606
6 "	16.7	2 females.	2	405	1023	2.7	10.94	11.00	6.50	1.13	24.2	.655
7 "	20.9	1 male. 3 females.	4	564	1018	1.1	6.20	7.00	5.63	.85	26.9	.296
8 "	22.6	2 males. 7 females.	20	628	1021.1	2.2	13.82	9.16	7.32	1.11	27.8	.611
9 "	26.2	1 male. 9 females.	25	731	1020.7	2.3	16.81	8.46	7.61	1.10	27.9	.641
10 "	27.5	2 males. 6 females.	15	768	1023.5	2.1	11.28	9.29	6.85	1.10	21.9	.592
11 "	27.2	1 male. 3 females.	7	716	1018.8	2.3	16.83	10.03	7.50	.92	26.3	.618
12 "	36.4	2 males. 3 females.	8	829	1021.5	2.8	23.21	9.27	6.77	1.00	22.7	.637

The quantities given in this table, although their accuracy is emphasized by the observer, are notably below those reported by others. Holt's[3] table, compiled by combining the results of eight observers, gives the average quantity at the ages of 2 to 5 years as 500 to 800 c.c.; at 5 to 8 years as 600 to 1,200 c.c.; at 8 to 14 years as 1,000 to 1,500 c.c. The amounts are also below those given by Vierordt in Gerhardt's "Handbook."

The specific gravity noted by Churchill is, as would be expected with the smaller quantity, notably higher than that given by other observers. The percentage of urea is also notably high and remarkably constant. The ratio of urea to 1 kgm. of body weight, while lower than that given by other observers, is still higher than that obtained in adult life.

The elimination of chlorides is not remarkable. The phosphates are lower than in adult life, the deficiency being explained on the ground that they are retained in the system to facilitate the development of bone which belongs to the period of childhood.

Carrière and Marfet thus sum up the results of their observations upon the urine in childhood:

1. The child voids relatively more urine than the adult.
2. The specific gravity is higher.
3. The acidity is greater.
4. The nitrogenous metabolism is more active than in the adult, that is, 1 kgm. of a child uses up a weight of nitrogen more completely, the adult percentage of utilized nitrogen being eighty-five, while in a child it is ninety.
5. The mineral nutrition shows marked differences, the younger organism being more highly mineralized.
6. All the phenomena of nutrition are much more active in the child than in the adult, the maximum being from the fifth to the tenth year.
7. The standard figures of the composition of normal urine for the adult are not applicable to children.

The process of urination in early childhood is marked by frequency and lack of control. In the third year the urine may be retained during sleep for eight or nine hours, during the day for two or three hours. Any unfavorable disturbance of the general health or impairment of nervous tone is marked in early childhood by loss of this control of the bladder. Incontinence of urine is a very common complaint at this period of life and is usually accompanied by a marked increase in the frequency of micturition, a child of three to five years often urinating every hour or even more frequently. In health the ability to control the bladder should at this period of life increase steadily with increasing years.

The Lymphatic System.—The lymphatics and lymph nodes in children are relatively large and much more active than in the adult. Absorption from the surface, either of skin or mucous membranes, occurs with marked rapidity. As a consequence the lymph nodes are found enlarged with unusual frequency. Indeed, enlargement of the lymph nodes, to such a degree as to render them palpable, is so common in children whose nutrition is under par or whose general care of the body is poor, that it assumes much less importance as a symptom of disease than we attach to it in later life. The lymph nodes are especially affected in tuberculosis and in all acute inflammatory processes, especially those of the throat.

The Nervous System.—In the comparison of a child with an adult the greatest disparity is found in the relation of brain weight to body weight. Thus at birth the brain weighs one-sixth the weight of the body, in the third year it is one-eighteenth, in adult life one-forty-third. The cord is also relatively large, although not to the degree noted with reference to the brain. Side by side with this large size of the nervous system we must note its unusual activity and sensitiveness during the early years of life. The normal healthy child during its waking hours is never still. Ceaseless action is an actual requirement behind which must lie a ceaseless activity of the brain and cord. Every sense is constantly on the alert for the new impressions that are pouring in upon the awakening mind, every muscle is in almost constant action in carrying out the impulses that result from these stimuli. Rapid development in the functions of the brain and nervous system marks the years of childhood. Recent investigations have shown that this mental development is accompanied by definite changes in the individual cells of the spinal cord and brain. The immature cells of the cortex or of the cord show steadily progressive changes in the development of new, more numerous, and more intricate communication with one another. Hand-in-hand with these rapid changes, both in functions and in physical structure, there goes a remarkable sensitiveness of the nervous system of the child. Children are, therefore, peculiarly subject to functional nervous disorders. Much of the irritability and peevishness of childhood is simply the expression of abnormal conditions of the nervous system.

In acute diseases of all kinds the nervous symptoms in childhood are likely to be very marked. The onset of the acute infectious diseases with convulsions is well known, likewise convulsions resulting from an overburdened stomach or from the decomposition of food in the bowels. It is less generally known that, especially in pneumonia, children may present many of the symptoms of meningitis, profound stupor, or coma, strabismus, rigidity of the neck, etc., without any involvement of the meninges, the severe nervous symptoms arising from the toxæmia of the pneumonia. Examples might be multiplied to show how sensitive the nervous system of the child is and how profoundly it may be affected by the condition of organs or parts apparently remotely connected with it. Perfect health of the whole body is essential to the equilibrium of the nervous system, and if we desire the best results in the development of intellect we must attend to the health of each and every part of the body.

Development of the Body.—It is evidently impossible to follow the development of the various organs and parts of the body in detail. Within recent years a vast amount of work has been done in measuring the height and weight of school-children of various ages and calculating the averages of large numbers. The accompanying table gives the results obtained by combining a large number of such tables. Naturally the larger the number of cases comprised in a table, the nearer the results approximate a true average. In comparing any two of the tables embraced in this computation, remarkable differences are at times notable; at other times the agreement between measurements of children in widely separated communities and under different social conditions is equally remarkable. The figures herewith given may be considered to represent a safe average for the field covered. In later observations along this line, notably those of Dr. W. T. Porter on the school-children of St. Louis, the girth of the chest is calculated for each year, also the probable deviation in any one of three factors—height, weight, and chest circumference. By comparison with such standards we may calculate how closely a child in its physical development corresponds to the average, and regulate its life accordingly.

AVERAGE HEIGHT IN CENTIMETRES AND WEIGHT IN KILOGRAMS OF CHILDREN. COMPILED FROM TABLES OF QUETELET, BRUSSELS; BOWDITCH, BOSTON; KOTELMAN, HAMBURG; PAGLIANI, TURIN, AND THE SWEDISH AND DANISH COMMISSIONS.

Age.	Height.	Weight.	Age.	Height.	Weight.
2–3 years.......	79.1	11	9–10 years......	126.1	25.6
3–4 "	86.2	12.5	10–11 "	129.8	27.6
4–5 "	92.4	13.8	11–12 "	133.9	29.6
5–6 "	102.8	16.9	12–13 "	138.2	32.1
6–7 "	109.4	19.3	13–14 "	142.8	35.2
7–8 "	115	21.4	14–15 "	148.5	39.3
8–9 "	120.4	23.4	15–16 "	154.6	45.4

In studying boys and girls separately certain differences are notable. Up to the eleventh or twelfth year boys are somewhat taller and heavier than girls of the same age. At the twelfth year the girls begin to grow rapidly, and from that time till the fourteenth or fifteenth year, the measurements of the girls are the larger. Then from fourteen to sixteen years the boys begin to grow rapidly, regain the lead and continue to hold it. This rapid growth, in girls from the twelfth to the fourteenth year, in boys from the fourteenth to the sixteenth, is spoken of as the prepubertal increase, as it is, of course, associated with the well-known earlier maturity of the female organism. Investigation has also shown that the growth, either in height or weight, is not continuous throughout the year. Spring and early summer are the time of most rapid increase in height, and in the course of a few months at this time most of the annual increase in height is accomplished. In a similar way most of the gain in weight is made in the latter part of summer and the fall. The winter, therefore, is a period of no gain; there may even be a loss of weight.

It is inadvisable in this place to attempt to discuss the physical and mental changes which belong to the transition from childhood to puberty. It may, however, be urged that the child's welfare, both of body and mind, demands such preparation for the changes that belong to this period, such education that the knowledge that must come shall come clean and undefiled. Parents and teachers have been too long negligent of these matters. They should be roused to their duties. The evil consequences of the policy of "*laissez faire*" are matters of common knowledge. It should no longer be permitted that any child should pass through one of the crises of life without a word of instruction or admonition as to the meaning of the changes that he or she must experience.

Mental Development.—To fully describe the mental development of childhood would require a complete psychology. What mainly interests us here is the initial stages. Bain[5] has given a simple account of these, and from him the following exposition is taken: In describing the mental status and progress of children, "there are," he says, "a few set phrases that are regularly brought into service. The child, it is said, has a great love of activity, a desire to be occupied somehow; dislikes continuous application or attention to any one thing; is joyous, mirthsome, fond of fun and frolic; delights in the exercise of the senses, and sensation generally; is curious and inquisitive even to destructiveness; is strongly given to imitation; is remarkably credulous; is imaginative and fond of dramatizing; is sociable and sympathetic. On the more exclusively intellectual side the child is prone to observation and averse to abstraction; strong in memory and weak in judgment."

He then proceeds to recast these observations in formal psychological terms under the several classes of activities, senses, emotions, and intellectual powers.

Activity is spontaneous and abundant, but fluctuating, uncertain, and indirect, being the outpouring and overflow of natural energy. Among the first efforts at education is the attempt to give it useful directions, but the readiest way is not to force it, but to take it at the moment when it is fallen on a good course.

The Senses.—These being fresh, and everything being new, sensation as such is delightful and coveted; hence the employment of the senses and the fruition of the effects are intense in infancy. But at first the emotional side preponderates, and the intellectual side, which is nourished by nice distinctions, does not attain an early development. The emotional force partly paves the way for, but partly obstructs, the intellectual.

The emotions, strictly so called, are distinguished from the sense enjoyments. These are mainly the strong social feelings, love and affection; the strong anti-social feelings, anger, egotism, domination, together with the workings of fear. All are powerful from the dawn of life; education, while connecting them with special objects, may do something to intensify or enfeeble their total force.

The Intellect.—The fundamental tendencies or functions—discrimination, discovery of agreements, retentiveness or memory, are at work from the first; but the active emotional development keeps them all down at the outset, although doing something that will provide materials that will be used in a future day. The operation of intellect is requisite to such complex growths as curiosity, imagination, dramatization, imitation, and fancy. The higher workings of intellect become necessary even to the observation of facts in any form that deserves the name.

Turning to the question of progress in mental development, Bain shows that the first start in knowledge is made through spontaneous and overflowing activity and in the interest of the impressions upon the senses; all which in the pristine freshness afford an abounding enjoyment. He then goes on to show how the child's field of knowledge is enlarged by attention to things or impressions which, not directly pleasurable in themselves, gain attention by association with the pleasurable. Thus the child is gradually led up to the acquisition of the indifferent, that is, knowledge devoid of the element of pleasure. However far along this path the child may be ied by mingling the indifferent with the pleasurable, the time comes when nothing short of the wish or will of a superior will keep the child to the acquisition of such knowledge. Fixed or concentrated attention to what is devoid of pleasure is unnatural and only to be secured by means of education.

It is evident from the foregoing that the early mental life of a child is made up of accumulating sensations or sense impressions. Most of these are very simple and crude. Only gradually does a child learn to observe closely or accurately. Still more slowly does he learn to associate his impressions one with the other, to compare them or to reach general propositions. According to one authority, it is years before the child learns to distinguish between the subjective and the objective. The power of abstract reasoning is developed, as a rule, only as the child nears maturity.

Study of the mental development of a child attains its all-important practical application in the arrangement of studies in the course of education.

Development of motor power and control should not be lost sight of in considering the growth of the mind. Gradually the child attains more and more control over the movements of the eyes, the imperfect speech of early years gives place to clear and distinct enunciation, the hands and feet are used with constantly increasing skill and accuracy, and finally, the movements of the several parts of the body may be co-ordinated in actions of extreme delicacy and complexity. Increasing strength should also naturally be developed in the years of childhood.

School Life.—All but the earliest years of childhood are now regularly occupied in attendance upon schools. The conditions of school life must, therefore, have most important influences upon the welfare of the child. It is coming to be recognized that however important education may be, it need not and must not be sought at the expense of the child's health. As Spencer[6] says: "People are beginning to see that the first requisite to success in life is to be a good animal." Care is being taken that schoolrooms are so constructed as to give proper light, heat, and ventilation, that the seats should no longer be so made as to directly contribute to deformities of the body, that the children are so seated as to avoid unfavorable straining of the eyes, that in every possible way the appointments of the schools shall contribute to health and not to disease. The tendencies of the times are plain, but there are unhappily many places where they are little felt.

In the larger cities daily inspection of the school-children by competent physicians has been instituted in the effort to prevent the spread of contagious diseases, of which the schools have been notorious hotbeds. In New York City many of the schools are thrown open as places of recreation for the pupils during the summer months.

Health of mind is no less to be sought than health of body. Recent years have brought great changes in the methods of school instruction, especially in the earlier years. The names of Pestolozzi and Froebel are constantly heard as the ideal teachers of the young, and the popular opinion is that their leading should be followed. As a matter of fact it is the spirit rather than the method of these men that still lives. The efforts made to follow their methods have resulted, as Oppenheim[7] very clearly shows, in much that is not only valueless but even harmful, yet on the whole the present education of the young is on a vastly higher and better level than ever before. Not a little of the change has been due to the teachings of such men as Spencer and Bain that the best method of education is that which observes the natural unfolding of the child's mind; that in the arrangement of studies or in the introduction or pursuit of any subject we should follow or consult the natural leadings of the mind of the child and not attempt to force it according to our preconceived ideas. Education is recognized as a process to be wrought out from within, and not to be put upon the child from without.

Moreover, much attention is now being given to the study of the immediate effects of confinement in school, hours of study, etc., upon the nervous system of the child, as these are shown by various nerve reactions. Nearly all such investigations go to show that our school sessions are altogether too long, that the periods of application to individual subjects are likewise too long, that there is not sufficient variety in the tasks assigned, and that the periods of relaxation are far too infrequent.

Pauli,[9] discussing this subject, advises one school session a day with limitation of the period of study of any one subject to three-quarters of an hour, with an interval of rest before the next study period.

A much-needed reform in these several directions may be looked for, but it is not probable that we shall ever be able to reach the ideal position, pictured by zealous advocates of reform, where the pursuit and acquirement of knowledge shall be an uninterrupted pleasure. Nay, were this hope realized, we would only have succeeded in destroying one of the most essential features in either physical or mental training, the ability to face and accomplish unpleasant or difficult tasks. That such things must be met in mature life is undoubted; that we should be trained to meet them seems, therefore, to be unquestionable. Theories of education should not lead us to ignore the teachings of common experience.

Disease in Childhood.—Partly by reason of susceptibility, partly from the conditions of life, childhood is pre-eminently the period of the acute infectious diseases, especially measles, scarlet fever, diphtheria, and whooping-cough. Greater attention to prophylaxis, especially the isolation of the sick and the disinfection of the infected room or apartment, is slowly but steadily lessening the ravages of these diseases. In the case of diphtheria the discovery of the specific micro-organism, resulting in earlier diagnosis and the early use of antitoxin, has produced a most remarkable reduction of the mortality, and to a larger extent robbed the disease of its terror. The other members of this group have thus far refused to yield the secret of their power, the pathogenic micro-organisms remain unknown, and progress waits on their discovery.

Affections of the respiratory system are not so common in childhood as in infancy, but still constitute a large part of the sick lists, and are responsible for many deaths. Bronchitis and broncho-pneumonia are the most common. Empyema is much less frequent, but not so rare as generally supposed. The latter is rarely primary; in the great majority of cases it follows a pneumonia, especially the complicating pneumonias of the acute infectious diseases. Tuberculosis limited to the lungs is rare in the early years of childhood; it becomes relatively more common later on, especially after the seventh year.

Disorders of the alimentary tract are very common in childhood, but are much less severe than in infancy. They are in great part acute inflammations produced by improper food and, as a rule, are readily amenable to treatment. As already stated, indigestion, constipation, and chronic diarrhœas from improper feeding are very frequent.

As a class, children are very susceptible to tuberculosis, which manifests itself in many forms. In the earlier years the common form is a general miliary tuberculosis. The terminal stage of such a general process is very frequently a tuberculous meningitis. The meningitis may occur independently of involvement of other organs, but rarely so. Recently in studying the reports of a large orthopædic dispensary and hospital the writer found that of all the deaths reported in cases of hip-joint or knee disease (nearly all of which are tuberculous), twenty-five per cent. were due to meningitis. Children with tuberculous disease of the bones (especially the spine and larger joints) constitute the major part of the clientèle of orthopædic institutions.

Tuberculous enlargements of the lymph nodes are very common in childhood.

Intestinal tuberculosis is common in children suffering from tuberculous processes in the lungs; as a primary affection it is very rare. The main avenue of infection in children is the respiratory tract. In the tables of Northrup and the writer,[8] out of two hundred autopsies on cases of tuberculosis in children, in three only were the intestines the port of entry, the remainder being all cases of primary infection of the bronchial lymph nodes. Therefore, while recognizing the possibility of intestinal infection from tuberculous milk or meat and taking every precaution to prevent entrance by that route, we shall not check the ravages of tuberculosis among children till we have solved the problem of preventing infection through the air they breathe.

Mortality.—The mortality of the early years of childhood (*i.e.*, from the second to the fifth year) is still high, but not at all comparable to that of infancy. Thus in round numbers the death records of New York City for 1899 in a population somewhat over 3,500,000 show 20,000 deaths in the first two years of life, 4,000 in the succeeding three years. In three years we have but one-fifth the number of deaths credited to the first two years of life. The contrast is even more remarkable with the later years of childhood. After the fifth year the number of deaths is calculated only for periods of five years each.

In 1899 in New York City there were but 1,815 deaths in children from five to ten years of age, while of those from ten to fifteen years but 788 died. As there is no means of calculating the numbers of children living of these several ages, we cannot calculate the ratio of deaths to the number of living. It is evident, however, from the data obtainable that the period from the tenth to the fifteenth year shows the lowest death rate of any equal period of life. Coincident with the fall in the mortality lists after the second year, there is a change in the causes of death. In infancy diarrhœal diseases are the great cause of death, while the acute infectious diseases take the first rank in childhood. Of these it is generally agreed that diphtheria and scarlet fever are the most malignant. Measles is not generally regarded as a dangerous disease, but in the same year, 1899, in New York City, there were 533 deaths from scarlet fever and 587 from measles. Upon the basis of cases of these diseases reported during the year, 7,387 for scarlet fever and 12,530 for measles, the death rate for scarlet fever is about 7.2 per cent., for measles, 4.6 per cent., yet the total loss to the community from measles is greater than that from scarlet fever. Doubtless the lack of appreciation of the malignity of measles is due to the fact that its ravages are greatest in hospitals or asylums, while in private families the disease is usually of a milder type; there is no such difference in the action of scarlet fever. Inasmuch as the deaths from diseases are not tabulated according to the ages of the victims, we have been obliged to assume that the total figures as given for all ages would have the same relations as those of childhood alone; considering the known predilection of these diseases for the years of childhood, this is probably true.

Next to the acute infectious diseases, the worst enemies of childhood are pneumonia and tuberculosis. There is nothing peculiar in the relation of pneumonia to childhood; it is the scourge of all ages. Tuberculosis in the early years, in a fatal form, is generally, as previously noted, either a diffuse process, affecting many parts, or tuberculous meningitis. As age increases a change is noticeable, and in the latter part of childhood pulmonary tuberculosis becomes the more common and deadly form of the disease.

It would be improper to leave this subject with the thought that the only importance of disease in childhood is the number of deaths caused thereby. The affections of childhood assume a new and greater importance when we consider the number of those affected who are destined, by reason of the permanent damages produced by disease, to enter the battle of life with impaired vitality and possibly a crippled body.[7] The waste, the suffering, the torture produced in this way is beyond computation

David Bovaird, Jr.

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CHILLIES. See *Capsicum, sp.*

CHINAPHTOL.—$(C_{10}H_6OHSO_3H)_2,C_{20}H_{24}N_2O_2$. Betanaphtol alpha-monosulphonate of quinine. This is a yellow crystalline powder of bitter taste, insoluble in cold water, somewhat soluble in hot water and alcohol, and containing about forty-two per cent. of quinine. Riegler states that in the intestines it is decomposed into quinine and naphtol-sulphonic acid, and therefore is both an intestinal antiseptic and an antipyretic. He has used it with satisfaction in typhoid fever, dysentery, intestinal tuberculosis, and acute rheumatism, in daily dosage of .5 to 5 gm. (gr. viij. to lxxv.). *W. A. Bastedo.*

CHINASEPTOL. — $(C_9H_5,OH,SO_3H,N.)$ Diaphtol, ortho-oxychinolin-meta-sulphonic acid. This occurs in yellowish crystals melting at 295° C. (563° F.), and is slightly soluble in water, the solution turning green with ferric chloride. Chemically it bears the same relation to chinolin as phenol-sulphonic acid bears to benzol. It is used as a non-poisonous antiseptic or as a substitute for salol. *W. A. Bastedo.*

CHINO, EL. — Within the municipality of Ucareo, Michoacan, Mexico, there are several springs—Laguna Verde, Nopalito Marítaro, Laguna Seca, etc. The only one that enjoys any reputation is "El Chino," to which people resort when suffering from rheumatism, sciatica, and other disorders. Bathers are compelled to erect their own tents if they wish protection from the weather and the curious. *N. J. Ponce de Léon.*

CHINOIDINE. See *Cinchona.*

CHINOLINE.—Chinoline, or *quinoline*, as it is also called, is a non-oxygenated basic body represented by the formula C_9H_7N, and obtained by the distillation of certain natural alkaloids—notably quinine and cinchonine—with potassium hydroxide, and also, synthetically, by a patented process (Skraup's), from a mixture of aniline, nitrobenzol, glycerin, and sulphuric acid. An isomeric body—*leucoline*—obtained from coal tar responds to chemical tests differently from chinoline, and is to be regarded as a distinct compound.

Chinoline is a colorless limpid fluid, of alkaline reaction, forming, with acids, crystallizable salts. Of such salts, those of the so-called mineral acids are mostly too deliquescent for convenient medicinal use, but chinoline *tartrate* is free from this objection and is available as a medicine. Chinoline tartrate is in minute, white, silky crystals, which, in a specimen made by Merck, of Darmstadt, the writer found to be of a faint combined bitter-almond and coal-gas odor, of a peculiar, sharp, yet cooling taste, having a flavor as of kerosene with a *soupçon* of peppermint, and to be slowly soluble in about twenty-five parts of cold water.

The effects of chinoline tartrate are analogous to those of salts of quinine. In solutions ranging from 0.2 to 0.4 per cent. it has been said to inhibit fermentative and putrefactive processes (Donath), and in doses such as would be given of quinine, to prove antipyretic and antiperiodic after the manner of that alkaloid (Donath, Loewy, and others). As against quinine, chinoline tartrate has the advantage of comparatively low price; but the disadvantage of a decided tendency to sicken, vomiting being quite a common consequence of a medicinal dose. Furthermore, later experience has failed to confirm the claim of antiperiodic powers at first asserted. The drug is best given in a sweetened aromatic water, and a teaspoonful of lemon juice or a lump of ice after the dose is said to lessen the tendency to nauseate

Neither chinoline nor any of its salts is official in the United States Pharmacopœia. *Edward Curtis.*

CHINOSOL. ($C_9H_6NO.SO_3K + Aq.$) Oxy chinoline sulphonate of potassium. This is a yellow crystalline powder of feebly aromatic odor, freely soluble in water and insoluble in alcohol and ether. Its dilute aqueous solution turns green with ferric chloride, and forms a green coating on steel instruments. It is stated to be a more powerful antiseptic than bichloride of mercury, with great penetrating power, and is highly spoken of by European clinicians; a 1-to-500 solution killed the plague bacillus in ten minutes. It has been used with advantage by Gilles in vaginitis in strength of 1 to 8,000 to 1 to 1,000, also in leprosy and bone tuberculosis. Mixed with five to ten per cent. of boric acid it may be used as an antiseptic powder in place of iodoform. Hobday found it a powerful disinfectant for the hands, the site of operation, and sutures, a solution of 1 to 60 producing no irritation. For cellulitis or other severe infection it should be used in strength of 1 to 500, but for ordinary use 1 to 1,000 is better. Cipriani recommends it by mouth and hypodermically for tuberculosis. It has also been used as an antipyretic. Hobday's experiments on cats indicate the limit of safe dosage to be .0037 gm. (gr. $\frac{1}{16}$) per 500 gm. (1 lb.) of body weight. Cadavers are said to be effectively preserved by intra-arterial injection of five-per-cent. solution.

Pulvis chinosol comp. consists of chinosol, chinaseptol, talc, and silica. *W. A. Bastedo.*

CHIRATA.—*Chiretta.* "The entire plant, *Swertia Chirayita* (Roxb.) Hamilton (fam. *Gentianaceæ*)" (U. S. P.) (It is spelled "Chirata" by Hamilton.) The following is the official description of this herb:

"Root nearly simple, about 7 cm. long; stem branched, nearly 1 metre long, slightly quadrangular above; containing a narrow wood circle and a large yellowish pith. Leaves opposite, sessile, ovate, entire, five-nerved. Flowers numerous, small, with a four-lobed calyx and corolla. The whole plant smooth, pale brown, inodorous, and intensely bitter."

Special attention should be given to this large pith, as there is a spurious article which is destitute of it, being quite hollow.

Chirata is a native of Northern India, especially in mountainous districts in Nepal, where it is found at an elevation of from five to nine thousand feet (Bentley and Trimen). Its use was introduced from India, where it has been long employed, into European medicine about fifty years ago.

The plant is gathered when fully grown; the flowering stems being pulled up entire, dried, and tied into long bundles.

In composition, Chirata is almost the exact equivalent of gentian, as it is also in properties and uses. Bitter *ophelic acid* ($C_{13}H_{20}O_{10}$), soluble in both alcohol and water, replaces the gentisic acid of the latter, *chiratin* ($C_{26}H_{48}O_{15}$), a yellow, bitter, crystalline glucoside, soluble in warm water and alcohol, replaces gentiopicrin, and as with gentian, there is no tannin, though ferric salts produce a dark color, without inky precipitate.

Chirata is a simple bitter and tonic. We have official a fluid extract, dose 1 to 4 c.c. (fl. ʒ ¼ to i.) and a ten-per-cent. tincture, made with sixty-five-per-cent alcohol, dose 1 to 8 c.c. (fl. ʒ ¼ to ij.). The latter is much the better preparation, especially in small doses.

Henry H. Rusby.

CHIROL is a solution of various oils and resins in ether and alcohol, forming an antiseptic varnish for the surgeon's hands. It is applied by immersing the hands, opening and shutting them a few times and spreading the fingers, then exposing them to the air for two or three minutes to dry. The pellicle formed is said to wash off easily, not to peel or crack, and not to be sticky. It covers the hands with a flexible, impermeable coating like a rubber glove. It has also been used for preliminary sterilization of the surface to be operated upon.

W. A. Bastedo.

CHITTENANGO SULPHUR SPRINGS. — Madison County, N. Y.

Post Office.—Chittenango.

Access.—This pleasant summer resort is located about 3 miles south of the Chittenango station, on the New York Central and on the New York, West Shore, and Buffalo railroads, between the beautiful villages of Chittenango and Cazenovia. The Springs are reached from Chittenango by an electric railroad, by carriage, and by a stage line.

The country surrounding the Springs is hilly and covered by a growth of hemlock, pine, beech, and maple. Through the valley between the hills flows the outlet of Cazenovia Lake to Oneida Lake, affording a stream twenty to seventy feet in width and well stocked with California, German, and brook trout. The hotel is large and commodious, with extensive verandas, spacious parlors, and high and well-ventilated rooms, capable of accommodating three hundred guests. The hillside grounds, in the rear of the hotel, including several acres, are covered with wild woods, intersected with walks, affording a cool and delightful strolling place in hot summer days. The Springs are three in number, known as the "White Sulphur," the "Magnesium Sulphur," and the "Lithium Sulphur" Springs. The following analyses were made by Professor Chandler, of New York:

One United States Gallon Contains:

Solids.	White Sulphur Spring. Grains.	Lithium Sulphur or Cave Spring. Grains.	Magnesia Sulphur Spring. Grains.
Magnesium carbonate	22.02	23.97	
Iron carbonate	......	......	20.78
Iron bicarbonate	.08	.16	.32
Sodium hyposulphite	......	.26	.02
Sodium sulphate	.21		
Calcium sulphate	81.42	106.12	115.09
Strontium sulphate	Trace.	Trace.	Trace.
Magnesium sulphate	1.95	7.59	12.72
Sodium chloride	1.04	1.57	1.83
Potassium chloride	.16	.23	.33
Lithium chloride	Trace.	Trace.	Trace.
Sodium sulphide	.12	.39	.75
Calcium sulphide	......	1.12	.93
Alumina	.08	.22	Trace.
Silica	.28	.52	.58
Total	107.36	142.15	153.35
Gases.	**Cubic ins.**	**Cubic ins.**	**Cubic ins.**
Sulphureted hydrogen	0.88	2.75	5.62
Carbonic acid	20.48	15.93	19.43

Temperature of water, 45° F.

The water of the White Sulphur Spring also contains a trace of free sulphur, which accounts for its pearly-white hue. This water is recommended for rheumatism, neuralgia, gout, and skin diseases. The magnesia water is transparent, but deposits a sediment said to consist of magnesia, yellow sulphur, and a chloride of potassium. This water possesses marked tonic properties, and is much used in general debility, nervous affections, and insomnia. The water of the Lithium Spring is also perfectly clear and very pleasant to the taste. It has enjoyed much reputation in the treatment of kidney affections. There is a large bath-house in connection with the Springs, in which hot mineral water, vapor, and electric baths are furnished. *James K. Crook.*

CHLOASMA.—(Synonyms: Liver Spot, Moth Patch, Mask; Fr., *Chloasme;* Ger., *Pigmentflecken.*)

Definition.—An abnormal pigmentation of the skin occurring usually in patches of yellow, brown, or black color, of various shapes and sizes.

It is used as a generic term and includes all discolorations of the skin, either circumscribed or diffuse, which are not accompanied by any other apparent objective changes. The color is of a yellow, brown, or black, changing in some conditions to a bronze or black (melanoderma). The discolorations may be unilateral, irregular, or symmetrical in their distribution, consisting of patches or of more or less diffuse pigmentations, stopping abruptly at the border, or they may shade off into the normal color of the part.

From the generic use of the term, chloasma is usually divided into the idiopathic or the symptomatic varieties.

Idiopathic chloasma is due to external causes or irritants: (1) Mechanical; (2) chemical; (3) thermal; (4) parasitic.

1. *Mechanical.*—As a result of abrasions and of trauma, and also in consequence of scratching, in pruritus senilis, prurigo, and other pruriginous diseases, deep pigmentation occurs in certain individuals, especially the run-down and elderly.

2. *Chemical.*—In this class may be placed those cases in which pigmentation follows sinapisms, vesicants, and counter-irritants. It is a question whether this is due directly to chemical effect or merely to the irritation. Tattooing may be placed here.

3. *Thermal.*—Bronzing following the erythematous stage of sunburn is not a true chloasma; it is simply a pigmentation of the exposed parts—deep brown in the case of blondes—produced by the sun's rays, and occurring generally in rather large and well-defined areas. Older people of a certain type have a tendency toward patchy pigmentation of the neck, arms, hands, and face, which is undoubtedly excited and increased by the sun's rays. Stokers and those exposed to hot fires often have peculiar darkened areas upon the exposed parts. Cold has been known to produce like conditions.

4. *Parasitic.*—De Amicis has lately described a peculiar café-au-lait pigmentation upon the chin and lip, due to the demodex folliculorum. Majocchi has likewise seen two cases. Pityriasis nigricans (Willan) is the deep pigmentation seen in vagrants and tramps, produced by scratching and generally due to pediculi corporis.

The various fungi which flourish upon the skin and cause yellowish or brownish spots, such as tinea versicolor, erythrasma, mal del pinto, are described under their respective titles.

Symptomatic chloasma may be a sequel of, or accompany, certain physiological or pathological conditions of the system.

After certain inflammatory skin diseases—*e.g.*, dermatitis herpetiformis, psoriasis, lichen planus, eczema, syphilitic eruptions, etc.—the sites occupied by the former eruption often display a yellow or brown pigmentation, a part of which is of hæmatogenous origin, while another part comes from the cells of the locality.

In cases of varicose veins the legs often have a deep patchy brown color, beginning about the follicles.

Chloasma uterinum is either a physiological or a pathological condition. Pregnant women usually have a deepening of the color, in pigmented portions of the body, of a greater or less degree. They also sometimes are affected with an abnormal deposit of pigment, which occurs in patches of a dirty yellow to brown color over the face, especially on the forehead, cheeks, and chin. Often it becomes diffuse in the shape of a sharply defined mask, the so called *masque des femmes enceintes*

In uterine and ovarian diseases a similar condition may be seen, the pigmentation occurring either in spots or in the form of a diffuse mask. In the latter case the neck is especially involved, though in this location the rough and tightly fitting ruffle or neck ornament may be a contributing factor.

In all cases of pigmentation of the face and neck the uterus and ovaries should be examined.

Various blood diseases of unknown origin (hæmatochromatoses of von Recklinghausen) are sometimes accompanied by abnormal pigmentation of the skin.

In exophthalmic goitre, abnormal pigmentation, in the form of patchy or diffuse freckles, is quite common, especially along the course of the musculo-cutaneous nerves on the hands and arms, and over those parts of the face which are supplied by the fifth nerve (Blake).

In abdominal tumors, tuberculosis, cancer, and lymphoma, pigment is common on the face and hands.

Diseases of the liver give rise more often to jaundice, but they are also accompanied by a patchy or diffuse pigmentation of the skin, often simulating, in this respect, Addison's disease, as is seen in diabetic cirrhosis.

It was formerly the fashion to ascribe, in a general way, all "moth spots" or patchy pigmentations to liver disorders (so-called "liver spots"). This idea was erroneous, for the pigment due to liver diseases is deposited more or less generally, and not in sharply circumscribed spots or patches, as is the case in the so-called "liver spots." These remarks may be also applied to malarial pigmentations, which are produced by chronic malarial poisoning.

Diseases of certain glands—*e.g.*, the suprarenal (Addison's disease) and the thyroid (Graves' disease) glands—are accompanied by dyschromias.

Pigmentations of varying degree and extent have been observed in cases of melanotic cancer and also in those of other forms of malignant growths.

Cachectic conditions often produce a universal deepening of pigment, from a sallow yellow to a yellowish-brown color. This is particularly true of tuberculosis, chronic rheumatism, syphilis, and leprosy; in the last-named disease the pigmentation is quite marked about the face and extremities in the late stages.

It is a fact which is often overlooked, that gastro-intestinal disorders play a rôle in certain cases of chloasma. Chronic constipation and intestinal and gastric fermentation of a chronic character, in which certain poisonous bodies are absorbed, produce besides other symptoms a patchy pigmentation of the face and hands, which is almost always symmetrically distributed.

Syphilitic pigmentation of the neck, usually seen in women, is accompanied by other local symptoms and does not belong here.

In respect to drugs, the most important discoloration is produced by nitrate of silver, for which see *Argyria*.

Arsenic also produces a brown or bronze pigmentation of the face, neck, and abdomen after prolonged administration of the drug, but, as I have endeavored to show, this is not an essential primary pigmentation, for it is always preceded by a sensible degree of inflammation of the skin

Little is known of the histopathology of chloasma. The pigment, in the more superficial forms, is deposited in the epidermis, either as something which was not there before, or else as an addition to a previously existing deposit; but in many varieties the cutis also contains a great amount of yellow granules, either in connective-tissue cells, which may form pigment themselves, or in the lymph spaces.

Van der Vegt found that in sections the epidermic pigment was soluble in a weak solution of caustic potash in peroxide of hydrogen, while that of the cutis was not soluble in this solution, though perfectly so in strong hydrochloric acid.

The *treatment* of chloasma consists simply in properly treating the cause or the disease upon which it is dependent. Consequently the reader is referred to the different articles which treat of the various conditions above mentioned. But no matter what the cause may be, the pigment is always slow to disappear; however, local treatment may in some cases assist in its removal. The results from local treatment depend, of course, upon the depth or location of the pigment. The remedies commonly used for this purpose cause desquamation of the epidermis, thus attempting by the desquamation to remove the pigmented cells. Some of these remedies are also supposed to have a bleaching effect, which at least is doubtful.

If after a thorough trial of the usual remedies no marked improvement is perceptible, treatment should be discontinued, as this probably shows that there is a deposit in the cutis, and such a deposit is often increased by continued irritation. Even in cases in which the spots are removed, there is often a reappearance with increased pigmentation.

The smaller areas can be very effectually removed by electrolysis, by inserting the needle just to the cutis margin, or by quick successive superficial stabs of the instrument.

Peroxide of hydrogen is recommended. It should be applied on cotton and allowed to remain on the spot several minutes. This procedure may be repeated several times a day.

The various scaling agents used are: salicylic acid in a saturated alcohol solution or in a paste; resorcin in from ten to twenty per cent. solution in alcohol or in a paste; corrosive sublimate, one per cent. in almond emulion; and nightly frictions of green soap. The following prescription is to be recommended:

℞ Hydrargyri ammoniati	℈ij.
Bismuthi subnitratis	℈ij.
Vaselini	℥i.
Olei rosæ	q.s.

M. Sig.: Apply gently to the discolorations at night, and wash off in the morning with green soap.

This ointment in the course of time will materially lighten the patches, and is greatly to be preferred to the strong lotions of corrosive sublimate, which often produce disastrous results. *W. A. Hardaway.*

CHLORAL.—By the title *Chloral*, Chloral, the United States Pharmacopœia recognizes not what is, chemically speaking, *chloral* proper, but an entirely distinct body, *chloral hydrate*. Chloral proper, C_2HCl_3O, is, chemically, acetic aldehyde (common aldehyde) with three atoms of hydrogen in the molecule replaced by chlorine. It is a thin, oily, colorless, heavy fluid. On mixing chloral with water the two bodies unite, forming a crystalline hydrate of chloral, C_2HCl_3O,H_2O, which is the substance used in medicine under the misnomer *chloral*. Chloral hydrate, or "chloral," appears in "separate, rhomboidal, colorless, and transparent crystals, having an aromatic, penetrating, and slightly acrid odor, and a bitterish, caustic taste; slowly volatilized when exposed to the air. Freely soluble in water, alcohol, or ether; also in chloroform, benzol, benzin, carbon disulphide, fixed and volatile oils. It liquefies when triturated with about an equal quantity of camphor, menthol, thymol, or carbolic acid. When heated to about 58° C. (136.4° F.) it melts, forming a liquid having a specific gravity of about 1.575, which at a higher temperature should not evolve inflammable vapors. Liquefied chloral solidifies to a crystalline mass between 35° and 50° C. (95° and 122° F.). Chloral is decomposd by caustic alkalies, alkaline earths, and ammonia, chloroform being formed, and a formate of the base produced. A freshly prepared aqueous solution of chloral is neutral, but gradually acquires an acid reaction" (U. S. P.). Chloral hydrate should be kept in glass-stoppered bottles in a cool and dark place.

Chloral hydrate was proposed as a medicine by Liebreich, in 1869, on the theoretical assumption that when absorbed into the circulation it would, by virtue of the warmth and alkalinity of the blood, undergo decomposition and conversion into chloroform. But, though chloral hydrate has proved itself a valuable medicine, it is now certainly known not to undergo the assumed decomposition in the circulation, so that its effects are those of itself as such, and not of chloroform.

The effects of chloral hydrate upon the animal economy, while much resembling those of chloroform, yet differ therefrom in many marked respects. Chloral hydrate, like chloroform, is locally a sharp irritant, and constitutionally a powerful neurotic, capable of producing arrest of the more important of the nervous functions, and so death. The most important difference between the action of chloral and that of chloroform is that the former drug has, relatively, a greater tendency to determine sleep, depression of respiration, and fall of temperature, and a distinctly less pronounced power to dull sensation, than has chloroform. In ordinary medicinal dosage (a single dose of from 2 to 3 gm., equivalent to from gr. xxx. to xlv.) the only marked effect of chloral hydrate is a gentle, calm, agreeable, dreamless sleep, which, if induced at bedtime, will, unless there be special reasons to the contrary, probably last till morning, and from which the waking will be natural, unattended by the disagreeable by-effects of an opiate. During the chloral sleep, forced awakening is as easy as during a natural heavy sleep, and the subject, when roused, is perfectly rational. Pulse and respiration are a little slowed, but otherwise the functions are not obviously affected. In increased dosage natural sleep deepens into coma; respiration, blood pressure, and pulse rate are markedly depressed, or the heart's action may be rapid while weak; temperature distinctly falls; sensation, after an initial temporary hyperæsthesia, becomes moderately blunted; motor paralysis, voluntary and reflex, comes on, and, if the dose has been sufficiently large, death ensues by failure of respiration; or, if the action has been sudden and overwhelming, death is by syncope, as in shock. The principal post-mortem revelation in fatal chloral poisoning is congestion of the lungs and of the cerebro-spinal axis. These various phenomena are undoubtedly produced by a direct action of the poison upon the nerve centres presiding over the functions deranged. Of the effects, those of greatest clinical importance are the hypnotism and the paresis of the respiratory centre and of the motor tract of the spinal cord generally.

When chloral hydrate is taken habitually, certain peculiar effects may follow. Perhaps the most common is some form of skin eruption, which is generally erythematous, though sometimes papular. In certain subjects, urticaria or purpura may result; in other cases, conjunctival or faucial irritation; in still others, dyspnœa; and in unique cases, pains in all the limbs and partial paraplegia have clearly been traced to chloral poisoning (Anstie). Quite a common effect, seen even in cases of single dosage, is one where chloral and alcohol have been taken together, namely, deep flushing of the face and throbbing of the vessels, exactly as produced by amyl nitrite. Prolonged habitual use of the drug probably tends to debase the mind and morals of the subject in the same manner as indulgence in alcohol, ether, or chloroform; and sudden discontinuance, after a fixed habit of excess, may naturally lead to the same consequences as the sudden breaking of a pronounced alcohol habit.

In the matter of toxicology, cases of fatal or of even dangerous poisoning have generally resulted from inadvertent medicinal overdosage. The smallest authenticated fatal dose is twenty grains (1.30 gm.), and the fact that such dose—one less than the usual medicinal dose—has killed only emphasizes the fact, now pretty generally recognized by the profession, that individuals show very different degrees of susceptibility to the action of chloral hydrate. The condition of dangerous poisoning is one of narcosis, distinguishable from the narcosis of opium, with which it is most likely to be confounded, by the conditions of the pupils. The pupils, in chloral poisoning, are either dilated, or if contracted are but moderately so, and dilate upon the subject's awakening. Very often, also, in chloral narcosis, the face is deeply flushed and somewhat bloated, the lips and eyelids swollen, and the eyes blood-shot. The treatment of poisoning by chloral hydrate is to evacuate the stomach, best by the stomach pump, and to sustain the flagging lungs and heart by artificial respiration. Medicinal respiratory and cardiac stimulants, though theoretically indicated, are practically of little use, because of the already hopelessly paralyzed condition of the tissue upon which they are to act.

Therapeutically, chloral hydrate is available to procure sleep, to oppose spasm, and to blunt pain. As a hypnotic it takes front rank among medicines, because of the combined certainty and yet pleasantness of its action. Yet the indiscriminate use of the drug in all conditions of wakefulness may easily work great harm. Thus, remembering the strong specific action of chloral hydrate to depress respiratory activity, it is plain that in the restlessness and wakefulness that result from dyspnœa, in such conditions as congestion of the lungs, emphysema, or bronchitis with obstructed circulation, the drug is the most improper thing that could be prescribed. Similarly, from its associated cardiac depression, all conditions caused or attended by feeble or embarrassed circulation contraindicate chloral. As an antispasmodic, chloral hydrate is peculiarly appropriate where the cause of the spasms is morbidly excited reflex irritability of the nerve centres. In tetanus it has thus worked many cures. As an anodyne this remedy is inferior to many others, as might be inferred from the fact, already mentioned, that anæsthesia is not a very pronounced element of its physiological operation.

A special use of chloral hydrate, not medicinal, yet utilized by the physician, is as a preservative. Like the related substances, the volatile alcohols and ethers, chloral hydrate is markedly antiseptic, and possesses the peculiar feature that, while preserving putrefiable tissues from decay, it yet does not obviously change the physical appearance of even the most delicate structures. The agent is, therefore, peculiarly useful as a preservative for urines set aside for microscopical examination. As much of the drug in crystals as will lie on the thumb-nail added to about 100 c.c. (about fl. ℥ iij.) of urine will preserve the same perfectly for days or even weeks, and that, too, without affecting the ready recognizability of casts, blood or pus corpuscles, epithelial scales, or spermatozoa. The addition does not affect the heat and nitric acid test for albumin, but it vitiates the test for sugar by Fehling's solution, since a solution of chloral hydrate of sufficient concentration will itself reduce the copper of that test fluid. The antiseptic action of chloral hydrate is available for use in surgery, and lotions of from one to three per cent. strength have been proposed for wounds. Such weak percentages are necessary, else the application will smart and perchance develop constitutional poisoning by absorption.

Lastly, chloral hydrate has been suggested as an anæsthetic for surgical use, by the procedure of injecting an aqueous solution directly into a vein. The quantity of one hundred grains has been so injected, with the effect of producing in eight minutes a complete anæsthesia that lasted an hour, and was followed by a deep sleep, with blunted sensibility, for fourteen hours. In other cases death has been reported as a consequence, as might naturally have been anticipated, and the procedure is little likely to find favor with conscientious surgeons.

For medicinal giving for its legitimate purposes, the dose of chloral hydrate for an adult should not at first exceed 1.30 gm. (gr. xx.). Often twice and three times that quantity is perfectly well borne, but, until the individual susceptibility of a given subject is tested, it is best to prescribe the smaller doses. The remedy is given in solution, with the sharp twang of the taste disguised by some syrupy and aromatic addition.

Edward Curtis.

CHLORAL ACETO-PHENON-OXIME.—$C_6H_5CH_3,C,NO,CH,OHCCl_3$. This is obtained by the interaction of chloral and acetophenonoxime at low temperatures. It occurs in colorless, prismatic crystals, insoluble in water, soluble in alcohol and ether, and decomposed by acids. It is hypnotic, and has been used in epilepsy and tetanus, but its effective dose has not yet been determined.

W. A. Bastedo.

CHLORAL ALCOHOLATE.—This body, C_2HCl_3O, C_2H_6O, forms during the process of manufacture of chloral from alcohol. It is in white crystals, distinguished from those of chloral hydrate by their insolubility in cold water, although they melt on admixture with hot water. This body is not used as a medicine, and needs mention only because it may possibly be mistaken in the market for chloral hydrate. *Edward Curtis.*

CHLORAL-AMMONIUM is obtained by passing dry ammonia gas through a solution of chloral in chloroform. It forms colorless needles melting at 84° C. (183.2° F.) and is almost insoluble in water. Boiled with water it forms chloroform and ammonium formate. It is given as an analgesic and hypnotic in dose of 1–2 gm. (gr. xv.–xxx.). *W. A. Bastedo.*

CHLORAL CAMPHOR.—This name has been applied to the clear fluid that results from trituration of equal parts of chloral hydrate and camphor. The fluid is soluble in alcohol, ether, glycerin, and fixed oils, but on mixture with water suffers precipitation of the camphor. It possesses the medicinal properties of its ingredients, and in a teaspoonful dose in one case produced severe, irritant, and narcotic poisoning. The compound is not official, but has been used medicinally as a nervous sedative in doses of from gtt. x. to xx. *Edward Curtis.*

CHLORAL CYANHYDRATE.—CCl_3COH,HCN, chloral hydrocyanin, chloral cyanhydrin. It occurs in small crystals or a crystalline powder having a mixed odor of hydrocyanic acid and chloral and readily soluble in water, alcohol, and ether. Its aqueous solution is only fairly stable, and it is decomposed by alkalies or boiling water. Hermes states that it has the action of hydrocyanic acid with about one-seventh its strength. A solution of 14.4 parts in sufficient water to make 100 parts corresponds with the Acidum Hydrocyanicum Dilutum of the United States Pharmacopœia. Six parts in 1,000 make a solution equivalent to the German Pharmacopœia bitter almond water. *W. A. Bastedo.*

CHLORALOSE.—$C_8H_{11}Cl_3O_6$, anhydro-gluco-chloral. By heating chloral and glucose together for an hour at about 96° C., chloralose and parachloralose are formed. The latter is not used in medicine. Chloralose occurs in fine, colorless needles or small crystals of bitter, unpleasant taste, soluble in 170 parts of cold water and readily soluble in hot water or alcohol. The crystals melt at 184°–186° C. (363.2°–366.8° F.). Following experiments on dogs, it was introduced in 1893 by Hanriot and Richet as a certain hypnotic devoid of depressing effects on respiration and circulation. In 1897 following experiments on man, Richet again recommended it highly, yet subsequent investigations have shown it to be extremely variable in its effects, and even unsafe in so small a dose as eight or ten grains. It is said to cause nausea, vomiting, slow weak heart, involuntary urination during sleep, and various nervous symptoms, such as delirium, tremors, and paralysis. The dose is 0.2–0.5 gm. (gr. iij.–viij.).

By treating arabinose and xylose in the same manner as glucose, the above investigators have obtained analogous compounds named respectively arabinochloralose and xylochloralose. The former is stated to produce quiet sleep without nervous symptoms and to be much less toxic than chloralose. Xylochloralose, however, was found to be more toxic and less hypnotic.

W. A. Bastedo.

CHLORALOXIMES are compounds of chloral with various oximes and are nearly insoluble in water, decomposed by hot water, and soluble in alcohol. The principal ones are chloralacetoxime, chloralcamphoroxime, chloral acetaldoxime, chloral nitroso-betanaphtoloxime, chloral benzaldoxime, and chloral acetophenonoxime. They all act as hypnotics (see *Chloral aceto-phenon-oxime*). *W. A. Bastedo.*

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